REMARKS/ARGUMENTS

Claims 1-7 were pending in this application. According to the April 3, 2003 Office Action, claims 1-7 were finally rejected. Applicant has amended claims 1, 3 and 5 and canceled claims 4, 6 and 7. Accordingly, claims 1-3, 4 and 5 are under consideration. Applicant maintains that the amendments do not introduce any new matter. Specifically, support for the terms "separating the solids from the liquid" and "eliminating the remaining solids in suspension from the liquid by flotation and coalescence of colloidal particles" may be found on page 5 of the specification on lines 23-25.

Rejection under 35 U.S.C. §103(a)

The Examiner rejected claims 1-7 under 35 U.S.C. §103(a) as allegedly being unpatentable over Pescher et al. in view of Rohrer and Waldmann.

In response, Applicant respectfully traverses the Examiner's rejection. The presently claimed process for treating manure is unique in providing so many advantages without generating harmful by-products. Nonetheless, claim 1 has been amended to replace the term "comprising" with "consisting of" thus excluding any additional steps.

The Examiner stated that the claims of the present patent application differ from Pescher et al. by reciting steps for introducing homogenized liquid manure into a tank, and eliminating liquid from a solid phase by flotation. Claim 1 as amended recites a step of "eliminating remaining solids in suspension from the liquid by flotation," and not "eliminating liquid from a solid phase by flotation." The incorporation of this additional steps is not obvious, as should be evident in view that nobody had achieved a so much optimized process.

The Examiner indicates that the treatment with inorganic oxidizing and [illegible]

[illegible]

could be the treatment with inorganic oxidizing and flocculating agents.

Applicant once again reiterates that the homogenization step is very important. It is respectfully submitted that according to Pescher et al the agents are added to the manure, and subsequently stirred. That is, the homogenization is performed simultaneously with respect to the step of stirring the agents into the manure. The same corresponds to the mixing disclosed in Rohrer. Opposite to this, according to the process disclosed in the present patent application, the homogenization is carried out prior to the addition of the polyacrylamide. This specific homogenization step was not disclosed nor suggested prior to the present patent application, and actually has important advantages, as it permits to reduce the quantity of polyacrylamide that is needed and optimizes to the maximum the interaction between the manure and the polyacrylamide.

Summing up, the process is optimized due to the previous homogenization and the concrete sequence of steps. Accordingly, the amount of polyacrylamide is also optimized and reduced to the maximum, so no excess polyacrylamide remains neither in the liquid nor in the solid. It has been experimentally checked that the content of polyacrylamide in the liquid can be considered non-existent, in any case below the critical level of 1 ppm. The measures have been performed by several recognized "Standard Methods." Further, it has been checked that no viscosity is present in the obtained liquid. Actually studies have been performed some time after the filing of the present patent application regarding the optimization of the quantity of polyacrylamide in the treatment of liquid manure: see "solid-liquid separation of flushed swine manure with PAM: effect of wastewater strength," 2002 American Society of Agricultural Engineers ISSN 0001-2351, page 1965, figure 3 (copy enclosed). In addition, applicant also encloses a copy of a report published on the web site http://www.cals.ncsu.edu/waste_mgt, wherein the advantages of the process according to the present patent application are further explained.

rejection.

In light of the foregoing, it is respectfully submitted that this application is now in condition to be allowed and the early issuance of a Notice of Allowance is respectfully solicited. If there are any issues or amendments the Examiner wishes to discuss, the Examiner is encouraged to contact the undersigned.

EXPRESS MAIL CERTIFICATE

I hereby certify that this correspondence is being deposited with the United States Postal Service as Express Mail to Addressee (mail label #EV 342531348US) in an envelope addressed to: Mail Stop RCE, Commissioner for Patents, Alexandria, VA 22313-1450, on October 3, 2003:

Dorothy Jenkins

Name of Person Mailing Correspondence

Dorothy Jenkins

Signature

October 3, 2003

Date of Signature

WOG/CCA:lac

Respectfully submitted,

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SOLID–LIQUID SEPARATION OF FLUSHED SWINE MANURE WITH PAM: EFFECT OF WASTEWATER STRENGTH

M. B. Vanotti, D. M. C. Rashash, P. G. Hunt

ABSTRACT. *Organic polymers are useful to increase separation of suspended solids and reduced carbon compounds from liquid swine manure. Along with the solids, there is a capture of the nutrients associated with small particles typical of these wastes. The combined effect increases the amount of materials available for value–added products, reduces the size of process units necessary to treat the liquid, and provides needed alternatives to land application. In this work, we evaluated the effect of solids strength typical of flushing systems on optimum polymer dose requirement and chemical use efficiency. Seven flush samples of varied strength were obtained two weeks apart during a three–month period in a feeder–to–finish operation (22.7 to 100 kg weight) in Bladen County, North Carolina. Treatments consisted of eight rates (0 to 140 mg L^{-1}) of polyacrylamide (PAM) followed by screening. Manure samples were characterized for solids, nutrients, and oxygen–demanding compounds amenable for separation. Their concentration varied greatly: 0.4% to 2.5% total solids (TS), 0.1% to 1.6% total suspended solids (TSS), 5.9 to 31.3 g L^{-1} chemical oxygen demand (COD), 0.7 to 10.6 g L^{-1} biochemical oxygen demand (BOD_5), 749 to 2442 mg total Kjeldahl (TKN) L^{-1}, and 96 to 585 mg total phosphorus (TP) L^{-1}. About 87% of P and 45% of N were organic forms, and 80% of TSS were volatile (VSS).*

Separation by screening alone was not effective; efficiencies were <20% TSS and VSS, <10% COD and BOD_5, and <15% N and P. Mixing with PAM before screening substantially increased separation; efficiencies using 140 mg L^{-1} rate were 95% TSS and VSS, 69% COD, 59% BOD_5, and 67% carbonaceous BOD_5. Inorganic P and N were not reduced by treatment. However, PAM significantly enhanced removal of both organic P and N (92% and 85%, respectively). For every 100 g of TSS removed, there was a 1.32–g reduction of COD, 3.32–g reduction of organic P, and 7.26–g reduction of organic N. The N:P nutrient ratio was improved from 4.79 to 12.11, resulting in a more balanced effluent for crops. It was more economical to treat flushed manure with the higher strength. Changes in optimum PAM rate were small (70 to 110 mg L^{-1}) and, consequently, polymer usage rate based on solids produced decreased significantly (from 5.34 to 0.75 g PAM/100 g dry solids separated) with increased wastewater strength. Therefore, reduction of total water volume to clean the houses can result in significant savings (about 700%) in total polymer cost. Chemical cost to capture 95% of the suspended solids was estimated to be \$1.37 to \$1.27 per finished pig for liquid waste containing 2% to 2.5% TS, respectively. Our results indicate that PAM technology can be enhanced for better liquid manure handling systems and associated management of nutrients.

Keywords. *Animal waste, Polymers, Swine wastewater, Solid–liquid separation, Liquid–solids separation, Phosphorus, Manure treatment.*

When properly managed, manure can be used to provide nutrients for crops and to build up soil organic matter. On the other hand, improperly managed manure and byproducts can pose a threat to soil, water, and air quality, and human and animal health. Manure nutrients in excess of the assimilative capacity of land available on farms are an environmental concern often associated with confined livestock production. Although the majority of the manure produced in confined operations is considered collectable, transport of this manure for long distances in a liquid form is not economically feasible. Thus, for farms producing excessive nutrients in liquid form, solid–liquid separation and distribution of solids to nutrient deficient areas could be a viable alternative. For the U.S. as a whole, in 1997 about 8% of the 1500 million pounds of farm–level excess nitrogen exceeded the assimilative capacity with existing crop acreage at the county level (Kellog et al., 2000). This means that most counties can handle the manure nitrogen generated if the manure is moved within a county. For phosphorus, about 20% of the 929 million pounds of farm level excess phosphorus exceeded the land assimilative capacity with the 1997 crop acreage at the county level (Kellog et al., 2000), indicating

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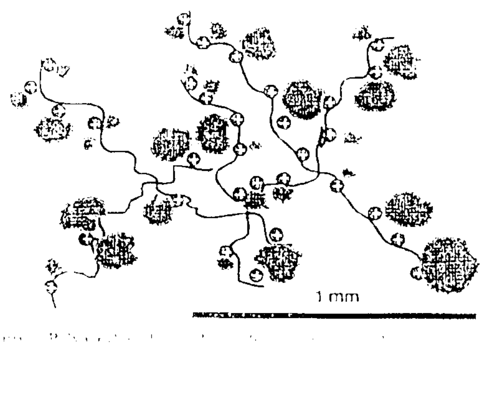
Mention of a trade name, proprietary product, or vender does not constitute a guarantee or warranty of the product by the USDA and does not imply its approval to the exclusion of other products or vendors that also may be suitable.

The authors are **Matias B. Vanotti**, Soil Scientist, and **Patrick G. Hunt, ASAE Member**, Soil Scientist, USDA–ARS, Coastal Plains Soil, Water, and Plant Research Center, Florence, South Carolina, and **Diana M. C. Rashash**, Area Specialized Agent, Environmental Education, [illegible]

Westerman (1997) indicated that it is necessary to remove particles smaller than 0.25 mm in order to effectively reduce nutrient and odor–generating compounds contained in liquid manure. Thus, separation of suspended solids from animal wastewater requires chemical treatment to bind together the small particles of solids into larger clumps (Sievers et al., 1994). Organic polymers and inorganic coagulants are both effective (Loehr, 1973; Vanotti and Hunt, 1999). The main advantage of organic polymers is that the amounts needed are about 10 times lower than those of inorganic substances, which minimizes generation of additional solids. Flocs obtained using organic polymers have a higher shear strength, i.e., more inter–particle bridging resulting from stronger elastic bonding. In addition, flocs obtained using inorganic coagulants are not very compressible; therefore, they take up more space on a filter medium and rapidly increase head loss (SNF Floerger, 2000).

Polyacrylamides are moderate to high molecular weight, long–chained, water–soluble organic polymers. The long polymer molecules destabilize suspended, charged particles by adsorbing onto them and building bridges between several suspended particles. This action results in newer, larger particles (flocs) that separate from the liquid and dewater more readily (fig. 1). Polymer flocculants have varied characteristics such as molecular weight and charge type (+, O, --), density distribution of charge (0% to 100%), chain structure, and comonomer that provide them with a variety of chemical performance characteristics and uses. For example, PAM is extensively used as a settling agent for food processing and packing, paper production, mine and municipal wastewater treatment, as a clarifier for sugar extraction and potable water treatment, and as a soil conditioner to reduce irrigation water erosion (Barvenik, 1994). Thus, PAM is widely available and relatively economical for several applications.

Vanotti and Hunt (1999) found that cationic PAMs with moderate charge density (20 to 35 mole %) were more effective than polymers with higher charge density for solid–liquid separation of swine manure and that neutral or anionic types were not useful for this application. Total suspended solids (TSS) removal efficiencies obtained were 90% to 94% when polymers were used in combination with a 1–mm screen but only 5% to 14% with the screen alone (control). Zhang and Lei (1998) also used cationic polymer and screening to flocculate and separate swine manure with 71% to 76% total solids (TS) removal and 77% to 84% volatile solids (VS) removal compared to only 15% and 17% without polymers, respectively. Both studies used fresh water to obtain diluted manure used in the evaluations. However, manure handling systems in confined swine operations generally recycle treated wastewater to clean the houses. Lagoon liquid and treated effluents contain high dissolved solid concentration, high ionic strength, and elevated electrical conductivity, which are parameters known to affect flocculation. Since the proportion of recycle liquid to fresh manure in flushing systems is high, polymer efficiency may be affected. Solids concentration of flushed manure also varies greatly among production facilities that use flushing systems and within growing stages in the same unit.



Our objective was to evaluate the effect of wastewater strength on separation of solids and nutrients from flushed swine manure in a situation where lagoon liquid recycle is used to clean the houses. In this work, we determined polymer use efficiencies in flushed manure of varied strength and established optimum polymer addition rates. Further, we evaluated relationships between solids separation and removable nutrients and oxygen–demanding compounds, and we determined changes in nitrogen to phosphorus ratio of treated wastewater that can result in improved land application strategies.

MATERIALS AND METHODS

SWINE WASTEWATER SAMPLES

Enhanced polymer separation of solids and nutrients from liquid swine manure was evaluated in laboratory experiments using flushed effluent that was collected during a three–month period from a commercial swine operation located in Bladen County, North Carolina. The operation was a feeder–to–finish operation [growing pigs from 22.7 to 100 kg (50 to 220 lb)] and consisted of four swine houses with concrete slatted floors containing 1200 pigs in each house. An under–slat flushing system typical of many livestock farms in the region was used to remove the manure from the buildings. The flushes were discharged into a single–stage anaerobic lagoon for treatment and storage of the wastewater. The treated liquid was subsequently land applied to nearby grass pastures. The water used for flushing the houses was a 100% recycle of the lagoon liquid supernatant. Each flush cycle was repeated five times per day and utilized 3.0 m^3 (800 gal) of lagoon liquid recycle to remove the waste from one side of each house. The flush was operated in an alternating mode, which provided a total of ten flushes per house each day for a total water usage of 30.3 m^3 (8,000 gal) per day for each 1200–pig building. This flushing schedule provided a fixed rate of 25 L wash water per pig per day, which was maintained throughout the production cycle of the pigs. Thus, the resulting total flush volume to animal weight ratio varied greatly with the size of the pigs from about 1110 L per 1000 kg live mass per day (17.8 ft^3/1,000 lb/day) at the

Table 1. Characteristics of flushed swine manure in a North Carolina finishing operation.[a]

Wastewater Parameter	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	P>F	CV (%)
Total solids (g/L)	4.30	5.7	7.55	9.73	11.40	12.57	24.8	0.0001	1.9
Total suspended solids (g/L)	1.47	2.19	4.39	5.33	7.21	7.63	15.84	0.0001	3.8
Volatile suspended solids (g/L)	1.13	1.72	3.84	4.17	5.65	6.38	12.59	0.0001	4.8
Chemical oxygen demand (g/L)	5.88	6.03	5.36	11.01	13.45	14.90	31.31	0.0001	8.1
Biological oxygen demand (g/L)	0.79	1.18	1.80	4.80	3.75	4.53	10.58	0.0001	11.7
Total phosphorus (mg/L)	96	111	144	235	350	367	585	0.0001	7.9
Inorganic phosphorus (mg/L)	25	49	27	21	47	89	72	0.0001	5.7
Organic phosphorus (mg/L)	72	63	117	214	304	278	513	0.0001	9.2
Total Kjeldahl nitrogen (mg/L)	903	855	749	1490	1302	1314	2442	0.0001	6.7
Ammonia–N (mg/L)	552	646	351	903	754	701	1164	0.0001	4.2
Organic–N (mg/L)	350	209	398	587	548	613	1278	0.0001	16.2
pH	7.8	8.1	7.0	8.5	7.9	7.9	8.0	0.0001	2.0
Electrical conductivity (mS/cm)	7.4	3.4	5.1	11.3	9.1	7.8	16.0	0.0001	0.3

[a] Flushes were obtained during a three–month sampling period. Individual pig weight increased from 22.7 kg (50 lb) in run 1 to 100 kg (220 lb) in run 7. Data are average of three replicates.

greatly affected the solids strength of the effluent wastewater during the growing cycle of the pigs (table 1).

A total of eight liquid manure samples was collected approximately two weeks apart during a three–month period to encompass the range of manure solids strength generated during a typical growing cycle; only seven were used. When the experiment started, the pigs weighed approximately 50 kg (110 lb) each. The waste obtained during a 55–day period was used for the first five polymer trials, with the last of these trials corresponding to animals of market size (100 kg or 220 lb). Another sample was obtained in the transition period when houses were about empty, but it was not used for polymer evaluation because strength was very low and similar to the lagoon liquid used to clean the houses. Two more samples were obtained 21 days apart with the new batch of pigs and used for two more polymer trials, representing the initial growth period between 23 kg (50 lb) and 39 kg (85 lb). The sample runs were labeled 1 to 7 following the approximate size of the pigs when samples were taken in the study (50, 85, 110, 140, 165, 190, and 220 lb/pig for runs 1 to 7, respectively).

The liquid manure samples were obtained from a mixing pit that collected the flush from the four houses before it was pumped to a screen solid–liquid separator. Samples were taken at the beginning, middle, and end of a flushing cycle from the second or third flush in the day using a bucket that held 7 L. The samples were combined to create composite samples that were collected in 18.9–L containers. The composite samples were transported on ice to the ARS Florence laboratory and were kept at 4° C to prevent digestion and dissolution of solids and organic nutrients. Polymer treatment experiments were performed the following day, and water quality determinations of treated and untreated liquid manure were initiated within 48 h of sample arrival. Samples of lagoon supernatant liquid used to flush the buildings were taken from the flush tanks prior to starting each of the flushes in the experiment and also analyzed for water quality characteristics.

POLYACRYLAMIDE

acrylamide and methyl chloride quaternary ammonium salt of dimethylaminoethyl acrylate. The comonomer provides the positive charge, and it is quaternized using methyl chloride to provide a permanent charge independent of pH. The Magnifloc G series products contain low amounts of residual acrylamide monomer and are marketed as flocculants and dewatering aids for food processing waste destined for recycling as animal feed, such as poultry wastes and corn processing wastes. Typical uses are to improve solid–liquid separation and reduce sludge volumes to rendering plants and for replacement of inorganic coagulants in dissolved air flotation processes. When used for these purposes and applied up to the indicated maximum dosage levels, they are considered Generally Recognized As Safe (GRAS) products (Cytec Industries, Inc., 1992; Schechter et al., 1995).

Flocculation Treatments

Flocculation and screening separation procedures were used to study the PAM dosage needs of the flushed wastewater with varied strength. The same procedures were applied to each of the seven composite samples using dry formulations of a cationic polymer. They included eight PAM rate treatments that were applied in increments of 20 mg/L, providing a final dosage range of 0 to 140 mg PAM/L. The exception was run 7 where PAM dosage was increased to 180 mg/L to better characterize the response. Composite samples corresponding to each run were transferred into 25–L vessels and stirred at 150 rpm with a high–torque laboratory mixer with a 7.87 cm (3.1 in.) diameter A 100 impeller (LabMaster SI, Lightnin Co., Rochester, N.Y.) to obtain homogeneous liquid manure subsamples. A peristaltic pump was used to transfer subsamples from the mixing vessel into eight 1–L jars used for the various PAM rate treatments.

After the jars were filled to the 500–mL mark with the well–mixed liquid manure sample, the chemical treatments were added to the wastewater with a syringe using 0.5% primary stocks (WERF, 1993). The stocks were prepared in stirred beakers with distilled water by first turning the bench stirrer (6.0 cm diameter impeller) to maximum speed (approximately 300 rpm) [illegible]

polymer injection, the samples were mixed with a bench stirrer at 100 rpm for 1 min and then at 40 rpm for about 2 min. The treated samples were passed through a perforated screen with openings of 1.0 mm and collected in beakers. Treatment performance was determined by the difference between the solids, nutrient, and COD concentrations in the effluent passing the screen and those in the initial sample before PAM application and screening. The separation experiments were repeated three times for each of the seven runs.

Solids analyses of the treated and untreated liquid samples included total solids (TS), total suspended solids (TSS), and volatile suspended solids (VSS). Total solids are the solids remaining after evaporation of a sample to constant weight at 105°C and include TSS and dissolved solids (DS). Total suspended solids (TSS) are the solids portion retained on a glass microfiber filter (Whatman grade 934–AH, Whatman, Inc., Clifton, N.J.) after filtration and drying to constant weight at 105° C, while volatile suspended solids (VSS) is the fraction of the TSS that was lost on ignition in a muffle furnace at 500° C for 15 min. Therefore, the TSS and VSS are measurements of the insoluble total and volatile solids that are removable by separation. The soluble fraction or dissolved solids can be determined by subtracting the TSS from the TS.

Chemical analyses consisted of pH, electrical conductivity (EC), chemical oxygen demand (COD), 5–d biochemical oxygen demand (BOD_5), 5–d carbonaceous biochemical oxygen demand ($CBOD_5$), ammonia–N (NH_3–N), total Kjeldahl N (TKN), orthophosphate–P (o–PO_4), and total P (TP). All the analyses were done according to Standard Methods for the Examination of Water and Wastewater (APHA, 1998). For COD, we used the closed reflux, colorimetric method (Standard Method 5220 D). Carbonaceous BOD_5 was determined using the 5–Day BOD test and nitrification inhibition with 2–chloro–6–(trichloro methyl) pyridine (TCMP) (Standard Method 5210 B). The inorganic o–PO_4 fraction, also termed "reactive P," was determined by the automated ascorbic acid method (Standard Method 4500–P F) after filtration through a 0.45–μm membrane filter (Gelman type Supor–450, Pall Corp., Ann Arbor, Mich.). The same filtrate was used to measure NH_3–N by the automated phenate method (Standard Method 4500–NH_3 G). Total P and TKN were determined using the ascorbic acid method and the phenate method, respectively, adapted to digested extracts (Technicon Instruments Corp., 1977). The organic P fraction is the difference between total P and o–PO_4 analyses and includes condensed and organically bound phosphates. The organic N fraction is the difference between Kjeldahl N and ammonia–N determinations. Nitrate–N was also measured in lagoon and flush samples but was not detected in any of the samples.

Statistical Analysis

Data were subjected to analysis of variance to evaluate PAM treatment rate effects and changes in wastewater characteristics among runs (SAS, 1988). Significant differences among treatment means were evaluated using a least significant difference (LSD) test at the 5% level. Linear and

Results and Discussion

Removable Solids and Nutrients

The solids and nutrient contents of the flushed manure during the various runs are shown in table 1. Manure samples used for run 1 through 7 correspond to flushes obtained periodically throughout the 50 to 220 lb weight range typical of feeder–to–finish production. Total solids (TS) strength of the flushes increased greatly during the production cycle, from 0.4% at the beginning of the cycle to a maximum of 2.5% at the end of the cycle. The range of TS obtained is consistent with values of 0.5% to 2% described for flush systems in the U.S. (Chastain et al., 1999). The total suspended solids fraction also varied significantly (from 0.15% to 1.6%) during the same period. On the average, 58% of the TS were suspended and removable by solid–liquid separation, and 80% of the suspended solids (TSS) were volatile solids (VSS). The TSS concentration was highly correlated with both COD concentration ($r = 0.98$) and BOD_5 concentration ($r = 0.97$). Therefore, removal of these constituents in significant quantities is linked to the successful separation of suspended particles from the liquid manure.

Nutrient concentration in the liquid manure also varied significantly among runs, with the highest TKN and TP concentration at the end of the production cycle (run 7). The soluble reactive P represented, on average, a small fraction (17%) of the total P in the flushes and was not significantly correlated ($p = 0.14$) with either TSS or TS. On the other hand, the organic P fraction made up a large proportion of the TP (87%), and this fraction was significantly ($p = 0.001$) correlated with TSS ($r = 0.98$) and TS ($r = 0.97$). For N, the ammonia fraction in the flushes comprised 55% of the TKN, while the organic N fraction comprised 45% of the total N. Changes in organic N concentration in the manure samples were closely associated ($r = 0.97$) with the variation in TSS. These results indicate that most of the organic N and P in liquid swine manure are contained in particulate solids and amenable to removal by solid–liquid separation.

The lagoon liquid used for flushing the houses contained a high TKN concentration that showed little variation throughout the three–month study (range 618 to 798 mg/L); about 79% of the total N was in the form of ammonia (table 2). The high ammonia in the cleaning water most likely decreased the proportion of organic N to total N in the flushes compared to a system where cleaner recycled water is used. Other soluble compounds were also present in high amounts in the recycle liquid; the average dissolved solids concentration was 2720 mg/L, and electrical conductivity was 6.8 mS/cm (table 2). Previous work on evaluation of PAM separation of liquid swine manure (Vanotti and Hunt, 1999; Zhang and Lei, 1998) used fresh–water flush or tap–water dilutions. The manure samples used in this work were obtained using cleaning water with high dissolved solids and ionic strength representative of flushing systems that use a recycling loop to clean the houses.

Removal of Solids and Nutrients by Screening

Homogenized waste from each run was passed through a

Table 2. Wastewater strength of lagoon liquid used to flush the houses compared to that of flushed manure.[a]

	Lagoon Liquid (1)	Flushed Manure (2)	Ratio (2)/(1)
Total solids (g/L)	3.32 (0.10)	10.89 (2.58)	3.28
Total suspended solids (g/L)	0.60 (0.03)	6.29 (1.82)	10.48
Volatile suspended solids (g/L)	0.46 (0.02)	5.07 (1.44)	11.02
Chemical oxygen demand (g/L)	2.04 (0.23)	12.56 (3.45)	6.16
Biological oxygen demand (g/L)	0.38 (0.09)	3.91 (1.27)	10.29
Total phosphorus (mg/L)	66 (7)	270 (67)	4.09
Inorganic phosphorus (mg/L)	37 (4)	47 (10)	1.27
Organic phosphorus (mg/L)	29 (7)	223 (61)	7.69
Total Kjeldahl nitrogen (mg/L)	673 (28)	1293 (218)	1.92
Ammonia–N (mg/L)	528 (21)	724 (98)	1.37
Organic–N (mg/L)	144 (37)	569 (130)	3.95
pH	8.2 (0.1)	7.9 (0.2)	0.96
Electrical conductivity (mS/cm)	6.8 (0.2)	9.3 (1.3)	0.73

[a] Means (SE) of seven runs. Individual run data for flushed manure are listed in table 1. Strength of lagoon liquid recycle varied little among runs, as shown by smaller SE.

Table 3. Reduction in concentration of suspended solids, COD, BOD_5, and nutrients in flushed swine manure by a screen separator.[a]

	Flushed Manure	After 1–mm Screen	Reduction in Concentration (%)
Total suspended solids (g/L)	6.29	5.33	15.3
Volatile suspended solids (g/L)	5.07	4.21	16.9
Chemical oxygen demand (g/L)	12.56	11.99	4.8
Biological oxygen demand (g/L)	3.91	3.64	6.8
Total phosphorus (mg/L)	270	243	10.0
Organic phosphorus (mg/L)	223	200	10.3
Total Kjeldahl nitrogen (mg/L)	1293	1200	7.2
Organic–N (mg/L)	569	497	12.7

[a] Means of seven runs and three replicates.

treatment *per se* was not effective in removing substantial amounts of suspended solids, oxygen demanding compounds, or nutrients from the flushed manure. Separation efficiencies were consistently low among the various runs. Furthermore, they did not increase over the range of flushwater solids strengths (0.4% to 2.5% TS) observed during this study (data not shown). On average, screening removed less than 20% of the suspended and volatile solids, less than 15% of the N and P, and less than 10% of the COD and BOD_5 (table 3). Hegg et al. (1981) and Holmberg et al. (1983) also reported low separation efficiencies of swine slurries with screens. Hegg et al. (1981) obtained removal efficiencies of 4% for TS and 9% for COD using a rotating screen of a 0.750 mm opening and slurries containing 2.4% TS. The removal efficiency increased to 8% and 16%, respectively, with slurries of about twice the strength (4.12% TS). For vibrating screens and 1.5% to 2.9% TS slurries, the percent TS removal they obtained ranged from 3% on a 1.574–mm screen to 10% on a 0.840–mm screen. Similarly, Holmberg et al. (1983) concluded that screening is not a useful practice for anaerobic digestion of flushed swine manure since a large portion of the reduced carbon remains in the liquid fraction. On the basis of COD removal, their data showed that only about 21% of the methane producing material is retained by screen [illegible]

shown in table 4. The data indicate that most of the suspended solids (80%), N (78%), and P (93%) that are potentially removable by phase separation were contained in very fine particles that passed a 0.297–mm screen. This indicates that screens of 0.5 to 1.6 mm opening size commonly used in mechanical screen–type commercial separators are not adequate with liquid swine manure. On the other hand, using screens or filters with small pore opening size (i.e., <0.2 mm) is difficult due to plugging with small particles and swine hair. These considerations illustrate the need for chemical flocculation treatment to enhance mechanical separation. With flocculation, the effective particle size is increased by agglomeration of small particles into a larger particle or floc (fig. 1). This larger size not only enhances solids retention by screens and separation of colloidal particles by settling (Vanotti and Hunt, 1999; Zhang and Lei, 1998) but also prevents clogging of finer filters such as sand filter beds (Vanotti et al., 2001).

To illustrate problems of poor separation with screens, we describe the following results obtained at the same production unit (4800 pigs) where the samples were obtained. In this unit, the waste liquid was passed through a stationary, inclined separator with a 1/16 in. screen before discharge into a lagoon (the study samples were taken from a homogenization pit before going through this screen). The farm contained two other identical units of 4800 pigs, each discharging into their own lagoon but without a screen solids separator. The TKN, TP and COD concentrations in the test and control lagoons were monitored during a 10–month period (Rashash et al., 1999). Results showed the lagoon that received screened effluent contained approximately 13% less TKN and 12% less TP than did the control lagoons; for COD, the differences were not significant. This case supports our conclusion that for flushed swine manure, screening alone does not provide substantial reduction of organic and nutrient loads to either existing lagoons or other treatment processes.

Enhanced Solid–Liquid Separation with PAM

Table 5 shows the effect of PAM dosage on average TSS, VSS, COD, and BOD removal from flushed [illegible]

Table 4. Retention of suspended solids and nutrients in flushed swine manure using screens of various sizes.[a]

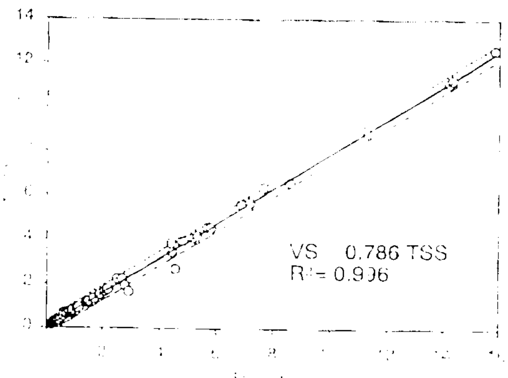
Screen Size[b]	Solids: Amount Retained (g/L)	Solids: Fraction of TSS (%)	TKN: Amount Retained (mg/L)	TKN: Fraction of Non-soluble N (%)	TP: Amount Retained (mg/L)	TP: Fraction of Non-soluble P (%)
3.360 mm	0.41	2.6	35	2.7	3.3	0.6
1.588 mm	1.01	6.4	100	7.8	11.1	2.2
1.000 mm	1.66	10.5	152	11.9	17.2	3.4
0.794 mm	2.18	13.8	199	15.6	21.9	4.3
0.590 mm	2.41	15.2	219	17.1	24.7	4.8
0.297 mm	3.10	19.6	278	21.8	38.0	7.4
<0.297 mm[c]						
Suspended	12.75	80.4	1000	78.2	475.4	92.6
Dissolved	9.03		1164		71.7	
Initial sample[d]						
Total suspended	15.84	100.0	1278	100.0	513.4	100.0
Total concentration	24.87		2442		585.1	

[a] Data are average of three replicate tests performed on run 7 effluent.
[b] 3.360, 1.000, 0.590, and 0.297 mm size screens are ASTM standard wire screen sieves with numbers 6, 18, 30, and 50, respectively. 1.588 and 0.794 mm size screens are stainless steel screens with round perforations of 1/16 and 1/32 in., respectively, commonly used in commercial screen separators.
[c] <0.297 mm is the fraction passing through this screen. This fraction was then filtered with a glass microfiber filter to separate between suspended and dissolved (soluble) components.
[d] Initial sample is the homogenized flushed manure before screening (table 1).

Table 5. Removal of solids, COD, and BOD_5 from flushed swine manure by PAM flocculation and screening.[a]

Polymer Rate (mg/L)	TSS: Conc.[b] (g/L)	TSS: Removal Efficiency[c] (%)	VSS: Conc.[b] (g/L)	VSS: Removal Efficiency[c] (%)	COD: Conc.[b] (g/L)	COD: Removal Efficiency[c] (%)	BOD_5: Conc.[b] (g/L)	BOD_5: Removal Efficiency[c] (%)
0	5.33 a	15	4.21 a	17	11.99 a	5	3.64 a	7
20	4.49 b	29	3.52 b	31	10.15 b	19	2.88 b	26
40	3.27 c	48	2.34 c	54	8.97 c	29	2.37 c	39
60	1.99 d	68	1.56 d	69	6.60 d	47	2.02 d	48
80	1.31 de	79	1.08 de	79	5.12 e	59	1.89 de	52
100	0.71 ef	89	0.59 ef	88	4.41 f	65	1.79 ef	54
120	0.43 f	93	0.35 f	93	4.00 f	68	1.73 ef	56
140	0.34 f	95	0.27 f	95	3.87 f	69	1.60 f	59

[a] Average of seven runs and three replicates. Different letters in columns indicate significant differences among means at $P \leq 0.05$. TSS = total suspended solids, VSS = volatile suspended solids, COD = chemical oxygen demand, BOD_5 = 5-day biological oxygen demand.
[b] Concentration in manure liquid passing 1-mm screen after flocculation treatment.
[c] Removal efficiency relative to concentration of flushed manure before chemical treatment and screening (table 2).



because preliminary tests (data not shown) indicated that effectiveness of the 1-mm screen to retain flocs was similar to effectiveness of a 0.8-mm size (95% and 96% TSS efficiency, respectively). However, the use of a larger screen (1.6 mm) greatly decreased performance (67% efficiency). Volatile suspended solids (VSS) were highly correlated with TSS (r = 0.996, fig. 2) and, therefore, the removal efficiencies of both fractions were almost identical (table 5). Averaged across all runs and treatments (n = 67), VSS comprised 78.6% of TSS (±0.5%).

Flocculation intensity increased linearly with increasing PAM rates up to an optimum level of "total flocculation" (WERF, 1993), where further increases of polymer dosage had little (non significant) effect on suspended solids concentration in the separated effluent. The response was different for the various wastewater samples, as revealed by a significant waste strength [illegible]

of polymer use to remove suspended solids from the more concentrated wastewater (fig. 3).

A linear plateau spline function was fitted to these data to determine optimum PAM application rates and maximum TSS separation at various wastewater strengths using non-linear least square iteration and a Gauss–Newton method (Freund and Littell, 1991). These parameters were then used to determine TSS removal efficiency and polymer efficiency based on TSS removal at optimum dosage. Results of these calculations are presented in table 6. Optimum PAM application rates did not change in the same proportion as TSS concentration. For example, TSS concentration varied 10–fold (1.5 to 15.8 g/L), while optimum polymer application rates varied less than 1 fold (from about 70 to 110 mg/L). There was a significant trend of increased polymer need with increased total solids concentration (optimum polymer rate = 57 + 2.17 TS, $R^2 = 0.95$). However, these changes in dosage requirements were small, in the order of about 11 mg/L PAM increase per 5 g/L TS increase for a range of about 0.5% to 2.5% TS found in the study. At optimum PAM rates, TSS removal efficiencies ranged from 87% to 96% (table 6).

Corresponding PAM use efficiencies (g TSS removed/g PAM) increased greatly from 18.7 to 133.6 with increased TS concentration (fig. 4). Polymer usage was also calculated in terms of lb of polymer per ton of dry solids produced to compare with other uses. At optimum flocculation, the weight of polymer used to produce a ton of dry solids ranged between 107 to 15 lb (5.34% to 0.75% TSS produced, table 6), and it was greatly affected by manure strength. The polymer usage rate obtained when the liquid swine manure had medium to high strength (TS > 0.75%, runs 3 to 7) was less than 40 lb/ton (<2%). This is within the range of typical wastewater and industrial applications (8 to 50 lb/ton). As explained in the following section, usage rates obtained with more dilute manure (TS < 0.60%, runs 1 and 2) were excessively high and costly.

Economic Considerations

Based on the results of polymer use efficiency obtained in this study (fig. 4), it is more economical to use PAM to remove solids and nutrients from swine manure wastewater when strength is higher in the range of normal operations. The chemical cost to flocculate suspended solids from flushed swine manure was calculated on the basis of treating the effluent from a 1000–head finishing operation growing pigs from 22.7 to 100 kg (50 to 220 lb). On average, each pig weighs 61.4 kg (135 lb). The amount of PAM required for 1000 pigs is 2.21 kg/day with the following conditions:

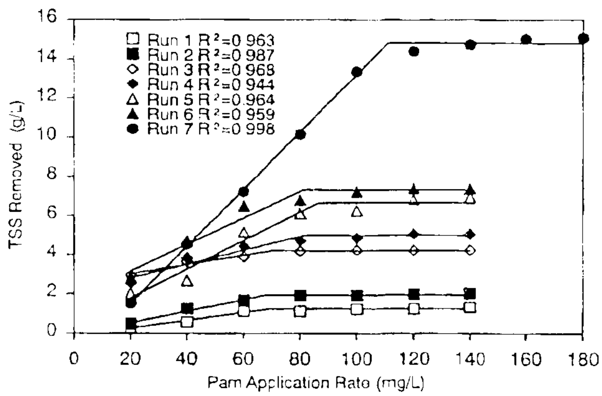


Figure 3. Capture of total suspended solids (TSS) from flushed swine manure using PAM treatment and screening (table 4). Corresponding optimum PAM application rates, maximum TSS removal, and TSS removal efficiencies are listed in table 6. Each point is the mean of three replicates.

Table 6. Changes in polymer use efficiency with wastewater strength.

		Regression Equation[a]						
Run	TSS Conc (g/L)	Slope (g/mg)	Optimum PAM Rate (mg/L)	Max. TSS Removed (g/L)	TSS Removal Efficiency[b] (%)	Polymer Use Efficiency[c] (g solids/g polymer)	Polymer Usage Rate[d] (%)	Polymer Usage Rate[d] (lb/ton)
1	1.47	0.0201	68	1.28	87	18.7	5.34	107
2	2.19	0.0291	68	1.95	89	28.6	3.50	70
3	4.39	0.0234	71	4.21	96	59.1	1.68	34
4	5.33	0.0355	82	4.99	94	61.0	1.63	32
[illegible]	7.21	[illegible]	87	[illegible]	[illegible]	77.2	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	15.84	0.1464	[illegible]	14.83	94	133.6	[illegible]	[illegible]

[illegible]

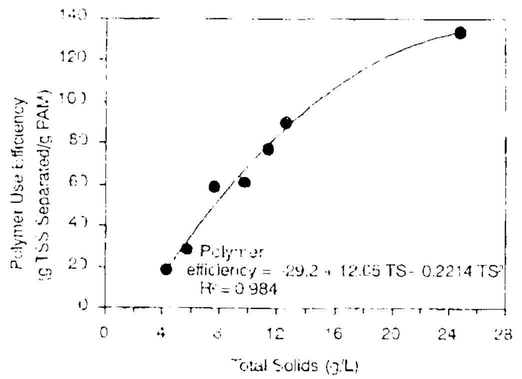


Figure 4. Effect of wastewater strength on polymer efficiency. Efficiency calculations are provided in table 6.

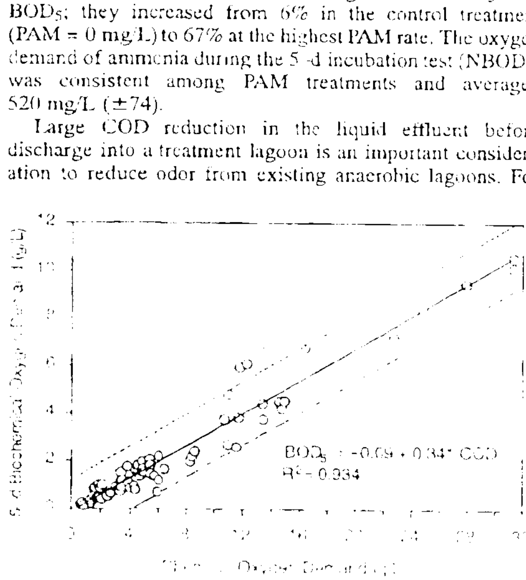
- Polymer usage rate of 0.75% (0.75 g polymer/100 g dry solids produced) associated with high–strength flushes (2.5% TS, run 7).
- TSS removal efficiency of 95%.
- TSS production rate of 5.05 kg/1000 kg live mass/day (NRCS, 1992).

The cost of PAM is approximately \$4.41/kg for dry formulations (\$2.00/lb). This results in a daily chemical cost of \$9.75/1000 pigs. For an operation that grows 2.8 groups of pigs per year, the annual chemical cost for the 1000–head operation is \$3,557, and the chemical cost per finished pig is \$1.27. This contrasts with the calculated chemical cost associated with a very diluted flush (0.4% TS, run 1). With a polymer usage rate of 5.34% (fig. 4), the chemical cost per finished pig is \$9.04, which is about seven times more expensive than treating higher strength waste. The flushing schedule used at the production facility provided a fixed rate of 25 L wash water per pig per day, which was maintained throughout the production cycle of the pigs. Thus, adjustments in management, such as reducing the frequency of flushing in periods when manure production is low so that a high wastewater strength is maintained, can result in significant savings in total polymer cost for separation.

The technology is also attractive for pit–recharge systems that are gaining popularity over flush systems because less water volume is required to clean the building. A pit–recharge system is typically emptied every five to seven days, resulting in a TS concentration that varies from 1.5% to 2.6% (Chastain et al., 1999). The chemical cost for this situation can be calculated based on polymer efficiency predicted by the equation in figure 4. This calculation indicates that treatment of liquid manure with 2% TS would be associated with a polymer efficiency of 123 g dry solids/g polymer (0.81% polymer usage rate) and a corresponding chemical cost of \$1.37 per finished pig. An important consideration for pit–recharge systems may be the potential for dissolution of solids in the pit, which can affect separation efficiency. Zhu et al. (2000) studied the problem and concluded that a 5–day storage should be satisfactory to maintain integrity of particles less than 0.5 mm for separation purposes.

to 59%, respectively (table 5). The COD is used as a measure of the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant. The BOD_5 test measures the oxygen utilized during a 5–day incubation period for the biochemical degradation of organic material (carbonaceous demand) plus the oxygen used to oxidize inorganic materials (APHA, 1998). The BOD determination is commonly used to determine the relative oxygen requirements of wastewaters, effluents, and polluted waters, and it is also applied to measure waste loadings to treatment plants and efficiency of these treatments. These two indicators of oxygen–demanding substances present in wastewater are closely associated; the empirical relationship (R^2 = 0.93) that we found for the liquid swine manure samples was 1 g COD = 0.341 g BOD (±0.011) (fig. 5). Although overall removal efficiencies were not as high as those obtained with suspended solids, as shown in fig. 6, most of the variation in COD (93%) observed after treatment was explained by the removal of flocculated suspended particles. On average, every 1 g of TSS separated from the liquid by treatment was associated with a 1.32–g reduction of COD (±0.03) and with a 0.394–g reduction of BOD_5 (±0.015). Because of the high concentration of soluble N (ammonia), which is not affected by polymer treatment, a fraction of the COD and BOD_5 measured in the treated effluent was due to ammonia oxidation (nitrification). We determined the effect of soluble N by measuring $CBOD_5$ and comparing with corresponding BOD_5 values so that the difference is the ammonia contribution. Measurements were done in the effluent of all treatments in five of the seven runs. Results showed that most of the variation in BOD_5 in the experiments was due to removal of carbonaceous materials (fig. 7). Overall removal efficiencies were higher for $CBOD_5$ than BOD_5; they increased from 6% in the control treatment (PAM = 0 mg/L) to 67% at the highest PAM rate. The oxygen demand of ammonia during the 5–d incubation test ($NBOD_5$) was consistent among PAM treatments and averaged 520 mg/L (±74).

Large COD reduction in the liquid effluent before discharge into a treatment lagoon is an important consideration to reduce odor from existing anaerobic lagoons. For



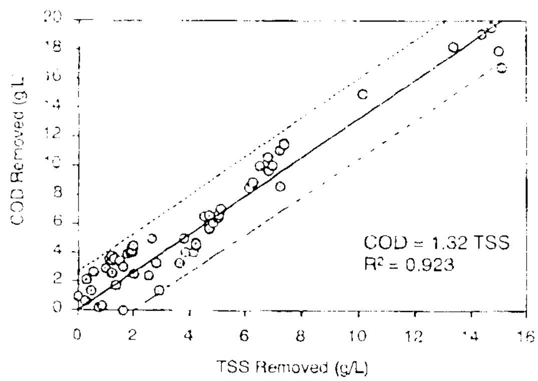


Figure 6. Relationship between the removal of chemical oxygen demand (COD) and removal of total suspended solids (TSS) by PAM treatment and screening. Data include eight PAM rate treatments and seven runs. Dashed lines indicate 95% CI for an individual prediction. Each point is the mean of three replicates.

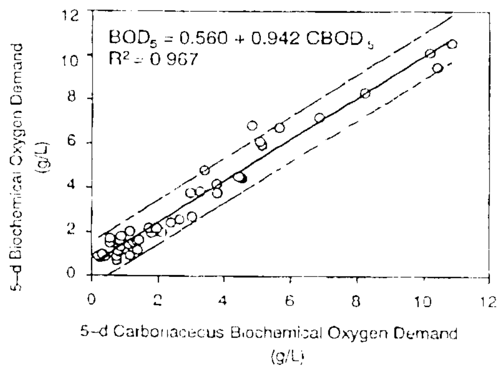


Figure 7. Relationship between BOD_5 and carbonaceous BOD_5 in the treated effluent. Data include eight PAM rate treatments and five flushed manure samples. Dashed lines indicate 95% CI. Each point is the mean of three replicates.

example, Humenik and Overcash (1976) indicate that odor is minimal with loading rates below 60 g of COD per m^3 of lagoon per day. This is approximately 40% to 76% lower than typical organic loads of 150 to 250 g COD m^{-3} d^{-1} used for lagoon design criteria (Burton, 1997). However, the minimal odor value is comparable to COD reduction levels obtained with PAM treatment. Our results indicate that PAM flocculation can substantially increase capture of energy-yielding feedstock for anaerobic digestion reactors, methane production, or burning in gasification processes, and that these materials can be effectively retained even with a relatively large screen (1-mm opening). These results are also significant to the swine producer who wishes to incorporate biological N removal processes for the purpose of ammonia control. By capturing the suspended particles, most of the volatile and oxygen demanding organic compounds are

Enhanced Nutrient Separation with PAM

Polymer treatment followed by screening significantly enhanced the removal efficiency of total phosphorus (TP) and total nitrogen (TKN) from 10% to 74% and from 7% to 35%, respectively, and significantly decreased nutrient concentration in the liquid phase (table 7). The effect of enhanced solids separation on nutrient removal was totally different for organic and inorganic compounds. The inorganic N and P fractions were not affected by PAM treatment; o-PO_4-P treatment means varied from 43 to 51 mg/L, and NH_3-N varied from 703 to 755 mg/L. This was also true for electrical conductivity (means ranged from 8.80 to 8.97 mS/cm) and pH (means varied from 7.82 to 7.97). On the other hand, PAM was very effective in the capture of organic nutrients contained in the small particles. PAM treatment increased removal efficiency of organic P and N from 10% to 92% and from 13% to 85%, respectively (table 7). Comparison of these values with suspended solids performance (table 5) indicates that for about 1% of TSS or VSS captured by PAM flocculation, a similar percentage of organic N or P is removed from the effluent. This indicates that organic nutrients in flushed effluent were mostly contained in suspended manure particles, which in turn were efficiently separated from the liquid by flocculation treatment.

The relationship for all treatments and runs between organic N and P separation and suspended solids separation as affected by PAM is shown in fig. 8. On average, 7.26 g of organic N (SE = 0.16) and 3.32 g of organic P (SE = 0.07) were removed from the liquid phase for every 100 g of TSS separated by PAM flocculation and screening. This enhanced removal of organic nutrients significantly improved the overall N:P ratio of the effluent. This is because, compared to N, a much larger fraction of total P in manure is made of organic compounds (for example, 87% vs. 45%, table 1). Since only the nutrients contained in the organic pool are affected by flocculation/separation treatment, separation of this N and P into the solid fraction effectively changes the N:P ratio of the liquid phase. As shown in table 7, effluent N:P ratios increased more than 100% with polymer treatment, from <5:1 to >11:1.

A higher N:P ratio results in a more balanced effluent from the point of view of crop nutrient needs. The implications are large; one of the main problems in sustainability of animal production is the imbalance between N and P in the waste. For example, the mean N:P ratio (4:1) in manure is generally lower than the mean N:P ratio (8:1) taken up by major grain and hay crops (USDA, 2001). Therefore, when manure is applied based on N, there is a P buildup in soil and increased potential for P losses through runoff and eutrophication of surface waters (Heathwaite et al., 2000; USEPA, 2001). Our results indicate that with a polymer-enhanced separation process, the treated wastewater is land applied with reduced total P loads.

Conclusions

[illegible]

Table 7. Removal of phosphorus and nitrogen from flushed swine manure by PAM flocculation and screening.[a]

Polymer Rate (mg/L)	TP Conc.[b] (g/L)	TP Removal Efficiency[c] (%)	Organic P Conc.[b] (g/L)	Organic P Removal Efficiency[c] (%)	TKN Conc.[b] (g/L)	TKN Removal Efficiency[c] (%)	Organic N Conc.[b] (g/L)	Organic N Removal Efficiency[c] (%)	N/P Ratio[d]
0	243 a	10	203 a	10	1200 a	7	497 a	13	4.94
20	214 b	21	177 a	21	1129 b	1[illegible]	437 b	23	5.28
40	167 c	38	121 b	44	1061 c	18	332 c	41	6.35
60	128 d	53	87 c	61	999 d	2[illegible]	291 d	49	7.80
80	99 e	63	52 d	77	960 e	2[illegible]	221 e	61	9.70
100	77 f	71	28 e	87	880 f	32	120 f	79	11.43
120	71 f	74	20 e	91	860 fg	3[illegible]	95 f	83	12.11
140	71 f	74	18 e	92	841 g	3[illegible]	85 f	85	11.85

[a] Average of seven runs and three replicates. Different letters in columns indicate significant differences among means at $P \leq 0.05$

[b] Nutrient concentration in liquid manure passing 1–mm screen after flocculation treatment.

[c] Removal efficiency relative to concentration before chemical treatment and screening (table 2)

[d] N/P ratio = TKN concentration/TP concentration. Average N/P ratio for initial sample was 4.79.

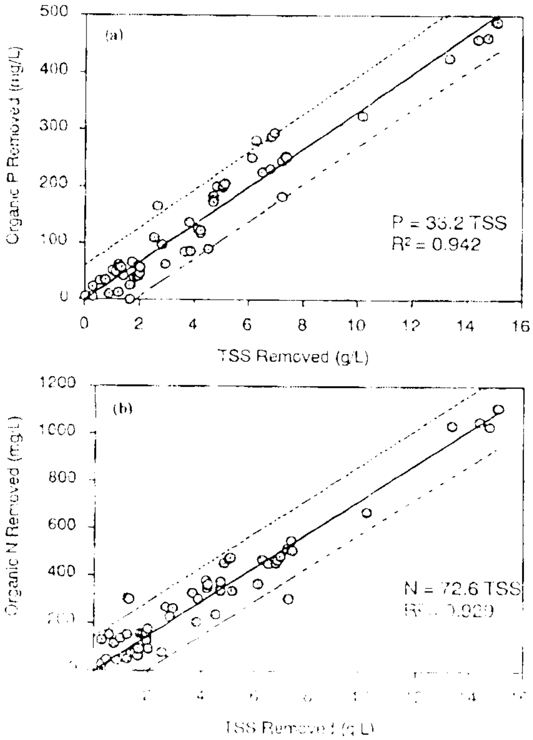


Figure 8. Relationship between the removal of (a) organic phosphorus or (b) organic nitrogen and the removal of total suspended solids (TSS) by PAM treatment and screening. Data include eight PAM rate treatments and seven swine waste effluent samples from a finishing operation. Dashed lines indicate 95% CI for an individual prediction. Each point is the mean of three replicates.

geographic areas. These spatial distribution problems could be solved if the nutrients were separated from the [illegible]

fractions that are potentially removable by phase separation were contained in particles less than 0.3 mm in size. Organic polymers offer a solution to this problem because they flocculate suspended and colloidal solids and, therefore, screening or filters after flocculation can capture the nutrients associated with small particles typical of these wastes.

Manure handling systems in confined operations often use large volumes of water to clean the houses. We evaluated the effect of typical flush–system solids strengths on both optimum polymer dose requirement and chemical use efficiency. We found that it was more efficient and economical to treat the higher strength flushed manure, over the range of 0.4% to 2.5% TS concentration that was evaluated. This study also showed that reduction of water volume to clean the houses can result in significant savings (about 700%) in total polymer cost by providing a higher strength waste for flocculation. Chemical cost was estimated to be $1.37 to $1.27 per finished pig for liquid waste containing 2% to 2.5% TS.

Flocculation treatment with PAM before screening substantially increased separation efficiency of TSS (95%), VSS (95%), COD (69%), and carbon BOD_5 (67%). For every 100 g of TSS removed, there was a 1.32–g reduction of COD, 3.32–g reduction of organic P, and 7.26–g reduction of organic N. PAM effectively removed organic nutrients (92% P and 85% N) but had no effect on the dissolved ammonia and phosphate fractions. The selective separation of the nutrients (organic vs. dissolved) increased the N:P ratio of the effluent (from 4.8 to 12.1), which resulted in a more balanced effluent for crop nutrient needs. This could help solve current problems of excess phosphorus accumulation in soils of wastewater spray fields.

Collectively, these findings indicate that:

- Polymer–enhanced solid–liquid separation of flushed swine manure is more efficient with higher solids content wastewater.
- When this technology is integrated into a liquid manure handling system, it has the potential to substantially increase capture of materials with potential to [illegible]

improved management of nutrients in areas where swine production is concentrated. Such secondary benefits need to be duly considered when determining the economic costs of the technology.

ACKNOWLEDGEMENTS

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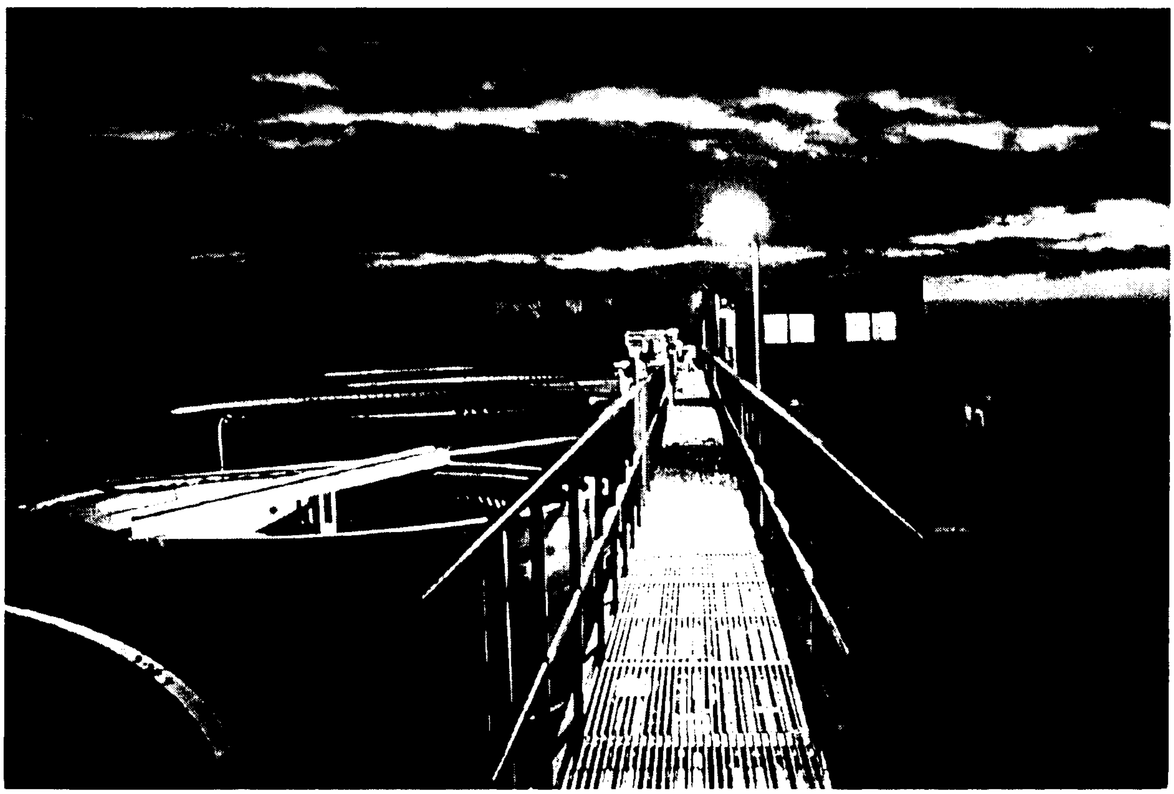
Evaluation of Environmental Superior Technology: Swine Waste Treatment System for Elimination of Lagoons, Reduced Environmental Impact, and Improved Water Quality.

(Solids separation/nitrification-denitrification/soluble phosphorus removal/solids processing system)

YEAR 3
PROGRESS REPORT

For the NC Attorney General – Smithfield Foods/Premium Standard Farms/Frontline Farmers Agreements



Prepared by

Matias Vanotti, PI

USDA-ARS

ProjectTitle :EvaluationofEnvironmentalSuperiorTechnology:SwineWasteTreatment SystemforEliminationofLagoons,Reduced EnvironmentalImpact,andImprovedWater Quality.(Solidsseparation/nitrification-denitrification/solublephosphorusremoval/ solidsprocessingsystem)

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TechnologyProvider:SuperSoilSystemsUSA,Inc

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CooperatingSub-Contractors

Solids-liquidseparation(EcopurinSolidsSeparation Module)andengineering:
SELCONetwork,M.C.,Castellon,Spain
Mr.JesusMartinezAlmela,GeneralManager, jmtnezalmela@selco.net

[illegible]

DevelopmentofInternationalMarkets forEnvironmentallyFriendlyPorkMeat andTrading :
Mitsui&Co.USA,Inc,Chicago,Illinois
Mr.ShigenaoSasaki,GeneralManager,S.Sasaki@xm.mitsui.co.jp

TechnologyDescription:

WasteStreamfromBarns →HomogenizationTank →SolidsSeparationwithPolymer →

(Liquid Phase) Nitrification/Denitrification → Clean Water Storage → Recycle to Barns → ExcessTreatedWatertoPhosphorus RemovalModule(MarketableProduct) →CropIrrigation.

(Solid Phase) Composting → Curing → Screening → Blending → Marketable Products (OrganicFertilizer,SoilAmendment,andSoillessMedia).

DurationDates : 10/01/2001–06/30/2002,extendedto12/31/2003

DatesCoveredforProgressReport: 10/25/2002–7/3/2003

ObjectivesofCurrentReportingPeriod:

Reportactivitiesre latedtodemonstrationofEnvironmentallySuperiorTechnologythatinclude theinitialtreatmentperformanceofthefull-scalewastetreatmentsystematGoshenRidgefarm (start-uptosteady-state),andactivitiesrelatedtoconstructionandinstallationoftheSolids Processingfacility.

AccomplishmentsforCurrentReportingPeriod:

1.PermittingandAgreements

- AllnecessaryagreementsandStatepermitsforthenewtreatmentfacilitiesatGoshen RidgeFarmandHickoryGroveRd.Farmhave beencompleted.Detailswereprovided inpreviousreport(July25-Oct.24,2002).

2.SolidsProcessingFacility(HickoryGrove)

- [illegible]

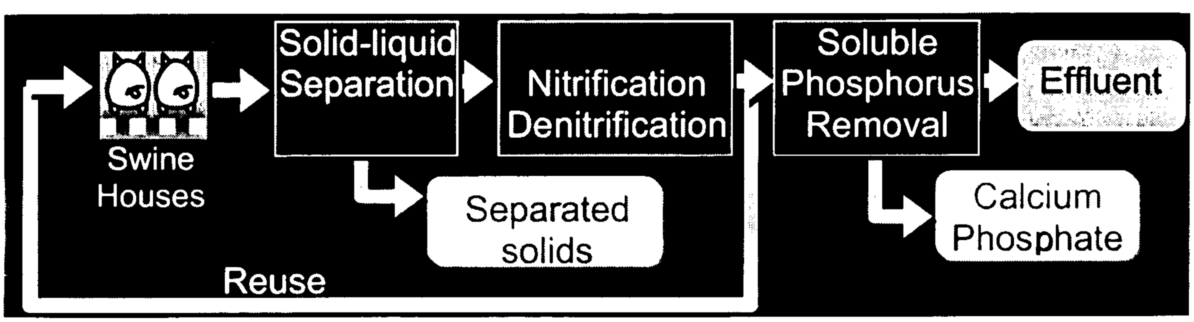
[illegible] completed.

- Automatedcompostingmachinerywillbeinstalledandbeoperationalbefore Aug.15, 2003.Additionalconcretepad(130x40ft)isbeingconstructedJuly2003tooptimize thenewmachinery.

3.ProductionFarmTreatmentFacility(GoshenRidge)

- <u>Background</u>:Systemsoftreatmenttechnologiesareneededthatcapturenutrients,reduce emissionsofammoniaandnuisanceodors,andkillharmfulpathogens.Asystemof swinewastewatertreatmenttechnologieswas developedtoaccomplishmanyofthetasks listedabove.Thesystemgreatlyincreasestheefficiencyofliquid/solidseparationby injectionofpolymertoincreasesolidsflocculation.Nitrogenmanagementtoreduce ammoniaemissionsisaccomplishedbypassingtheliquidthroughamodulewhere immobilizedbacteriatransformnitrogen. Subsequentalkalinetreatmentofthe wastewaterinaphosphorusmoduleprecipitatescalciumphosphateandkillspathogens. Treatedwastewaterisrecycledtocleanhoghousesandforcropirrigation.Thesystem hasbeenpilottestedandisgoingthroughfull-scaledemonstrationandverificationas partoftheSmithfieldFoods-PremiumStandardFarms/NorthCarolinaAttorneyGeneral agreementtoidentifytechnologiesthatcanreplacecurrentlagoonswithEnvironmentally SuperiorTechnology.Ifthefull-scaledem onstrationprovestobesuccessful,the technologycanbeusedinnewsystemswherethelagoonisomitted.
- Thefull-scaledemonstrationfacilitywas installedinGoshenRidge,a4,400-head finishingfarminDuplinCounty,NC.Theon-farmsystemusespolymerliquid-solid separation,nitrification/denitrification,andsolublePremovalmodules.Thesystemwas constructedbySuperSoilSystemsUSAofClinton,NC.Thetotalsystemiscompleted withthecentralizedsolidprocessingfacility(section2above)atSuperSoilSystems USAheadquartersinSampsonCounty,NC, whereseparatedmanuresolidswillgo throughaerobiccompostingandblendingprocessestoproducevalue-addedproductsto includeorganicfertilizer,soilamendments,andproprietarysoillessmediaforusein horticulturalmarkets.

- Constructionandinstallationofthetreatmentfacilityat GoshenRidgefarmstartedin February2002andwascomplete dinOctober2002.Constructiondetailswereprovided inpreviousreport(July25-Oct.24,2002).Thefollowingdiagramillustratesthe treatmentsysteminstalled:



3.1Samplecollectionandanalyticalmethods

- Liquidsampleswerecollectedusingfourrefrigeratedautomated(Sigma900max)samplersplacedbefore andaftereachofthetreatmentmodulesasfollows:1)theuntreatedliquidmanureinthemixingtankbefore solidsseparation,2)theeffluentfromthesolid-liquidseparationtreatment,3)theeffluentafterthe nitrification-denitrificationtreatment,and4)theeffl uentafterthephosphorusremovaltreatment.Each samplewasthecompositeoffoursub-samplestakenovera3.5dayperiod.Exceptduringthefirstfive weeksofevaluationoftheseparationmodulewhensub-samplesweretakenbysamplerstwiceaday(3am and3pm)andcompositeddailytoevaluatemixingofthehomogenizationtank.AfterTSSanalyses,these sampleswerecombinedinthelaboratoryintotwoweeklysamplesfortheotherwaterquality determinations.Fortheseparatedsolids,wecollectedonesamplefromeachtrailerleavingthefarm. Samplesoflagoonsupernatantliquidwereobtainedmonthlyfromeachofthethreelagoonsinthefarm;a samplewascollectedbycombiningeightsub-samplestakenaroundalagoon.Onceaweek,liquidand solidssamplesweretransportedonicetotheARSFlorencelaboratoryforanalysis.Aftermoisture determination,thesolidsamplesfromindividualtrailerswerecombinedintotwoweeklysamplesfor chemicalanalyses.

- WastewateranalyseswereperformedaccordingtoStandardMethodsfortheExaminationofWaterand Wastewater(APHA,AWWA&WEF,1998).Solidsanalysesofthetreatedanduntreatedliquidsamples includedtotalsolids(TS),totalsuspendedsolids(T SS),andvolatilesuspendedsolids(VSS).Totalsolids arethesolidsremainingafterevaporationofasampletoconstantweightat105°CandincludeTSSand dissolvedsolids(DS) Totalsuspendedsolids(TSS)arethesolidsportionretainedonaglassmicrofiber filter(Whatmangrade934-AH,Whatman,Inc.,Clifton,N.J.)afterfiltrationanddryingtoconstantweight at105°C,whilevolatilesuspendedsolids(VSS)isthefractionoftheTSSthatwaslostonignitionina mufflefurnaceat500°Cfor15min.Therefore,theTSSandVSSaremeasurementsoftheinsolubletotal andvolatilesolidsthatareremovablebyseparation.

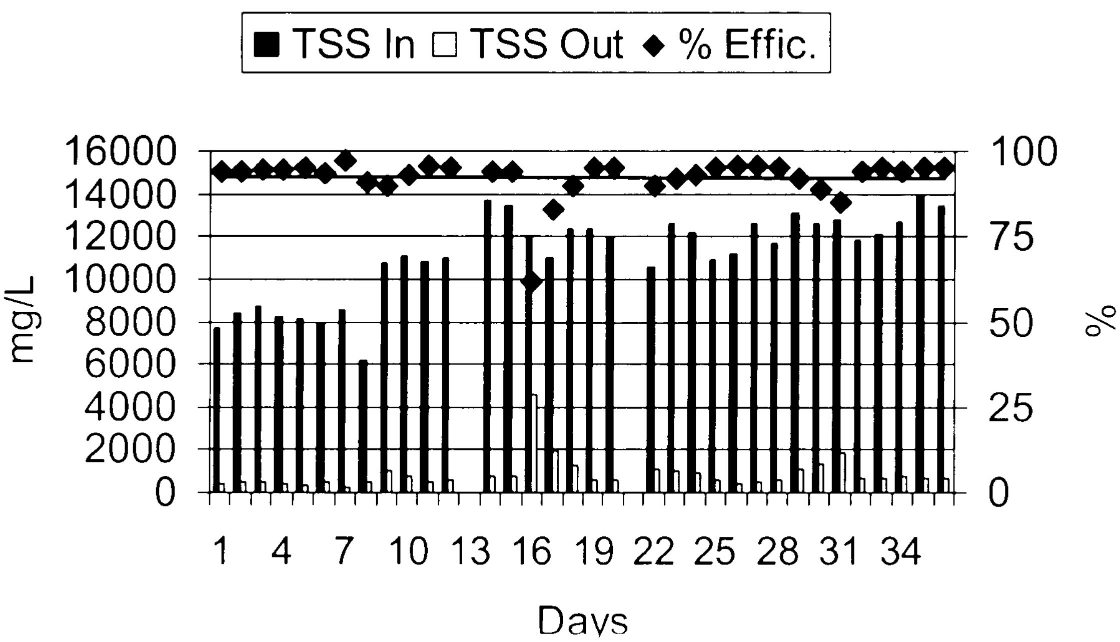
- ChemicalanalysesconsistedofpH,electricalco nductivity(EC),chemicaloxygendemand(COD),5-d biochemicaloxygendemand(BOD_5),ammonia-N(NH_3-N),totalKjeldahlN(TKN),orthophosphate-P (PO_4),andtotalP(TP) ForCOD,weusedtheclosedreflux,colorimetricmethod(StandardMethod5220 D).Theorthophosphate(PO_4-P)fractionwasdeterminedbytheautomatedascorbicacidmethod(Standard Method4500-PF)afterfiltrationthrougha0.45-µmmembranefilter(GelmantypeSupor-450,PallCorp., AnnArbor,Mich.).ThesamefiltratewasusedtomeasureNH_4-Nbytheautomatedphenatemethod (StandardMethod4500-NH_3G),NO_3 –Nbytheautomatedcadmiumreductionmethod(StandardMethod 4500-NO_3^-F),andsolubleCOD.ParticulateCODisthedifferencebetweenCODandsolubleCOD.Total PandTKNweredeterminedusingtheascorbicacid methodandthephenatemethod,respectively,adapted todigestedextracts(TechniconInstrumentsCorp.,1977).TheorganicPfractionisthedifferencebetween totalPandPO_4analysesandincludescondensedandorganicallyboundphosphates.TheorganicNfraction isthedifferencebetweenKjeldahlNandammonia-Ndeterminations.Alkalinitywasdeterminedbyacid titrationtothebromocresolgreenendpoint(pH 4.5)andexpressedasmg$CaCO_3$ L^{-1}.Microelements weremeasuredinacidextractsusinginductivelycoupledplasma(ICP)analysis.Solidssampleswere analyzedformoisturecontentusingamicrowavemoistureanalyzer.Drysamplesweredigestedwith concentratedacid(Gallaheretal.,1976)andtheextractswereanalyzedforTKNandTPwiththe automatedmethoddescribedbefore.

3.2 EcopurinSolid-LiquidSeparationModule

[illegible]Polyacrylamideswerefoundtobeeffective.Thesolidsinthe treatmentfacilityareseparatedfromthe liquidwiththeEcopurinseparationmodule

developedbyaSpanishcompany,SelcoMC.Themoduleiscontainedinaseparation building.Itisfullyautomatedthroughtheuseofaprogrammablelogiccontroller(PLC) for24hr/dayoperation.Treatmentparameterssuchaspol ymerrate,wastewaterflow andmixingintensityaresetbytheoperatorusingatactilescreeninthecontrolpanel.In themainmodule,theliquidmanureisreacte dwithpolymerandseparatedwithaself-cleaningrotatingscreen.Subsequently,adissolvedairflotationunit(DAF)polishesthe liquideffluentwhileasmallfilterpressdewatersthesolids.Thedewateredsolidsfallin a120ft^{3}trailerandtransporteddailytothecentralprocessingplant.Theseparatedliquid isdischargedintoasmallconcretepitwher eitiscontinuouslypumpedintothebiological Nremovalmoduleforfurthertreatment.

- Duringthefirst49daysofevaluation(M arch5-April23,2003),theseparationmodule operatedataflowrateof2.5m^3/h.Althoughthisrateishalfthedesigncapacityofthe separationmodule(5m^3/h),theamountofrawmanurewasinsufficientfora7daysper weekoperationandtheflowratewasfurtherreducedto2m ^{3}/hduringtheremainderof theevaluation.Thiswasimportantinordertoprovidecontinuousflow7daysaweekto thebiologicalmoduleandoptimizethetotal system.Polymeradditionratewasset constantat120ppmexceptduring1.5weeksatthebeginningofJunewhentheratewas increasedto180ppmtooptimizepressdewatering withtheveryhighsolidconcentration manure(>1.5%TSS)obtainedattheendoftheproductioncycle.



[illegible]
duringfirstfiveweeksofevaluation. 24-hsamplestakenat3amand3pm.

- Data in Fig. 1 show the TSS separation efficiency of module during first 5-wk of evaluation when samples were taken daily to confirm that liquid manure in homogenization tank was well mixed between the two weekly flushes. Separation efficiency was consistently high with an average of 94% TSS separation. This high-separation efficiency was maintained during the 4-month evaluation period summarized in this report (Table 1 and Figure 2).

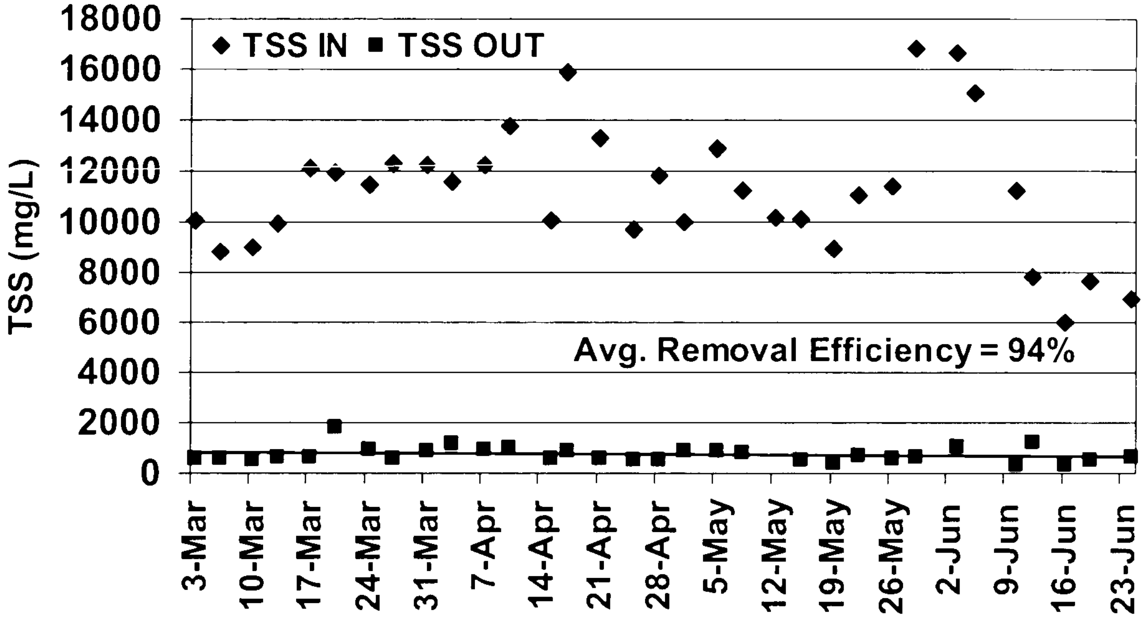


Figure 2: Total suspended solids (TSS) concentration in liquid swine manure before and after solid-liquid separation treatment during the first four months of evaluation. 3.5-d composite sample evaluation.

- Treatment performance of the separation module for a variety of water quality parameters is summarized in Table 1. The process separated most the suspended solids, and oxygen demanding compounds and organic nutrients associated with these solids. Reduction of suspended organic compounds is an important consideration for the efficiency of the nitrification treatment, while capture of carbon and organic nutrients is important for the efficiency of the solids processing operation. Soluble ammonia and phosphate concentration changed little (< 7 and 17% reduction, respectively) with separation treatment. On the other hand, organic N and P were effectively captured in the solids resulting in [illegible]

[illegible] indicate that both copper and zinc were trapped by the polymer and efficiently removed (>95%) from the liquid phase using the solid-liquid separation module (Table 1).

Table1:Removalofsolids,nutrient,CODandheavymetalcompoundsfromliquidswinemanurebysolid-liquidseparationmodule(Ecopurinprocess).Dataaremeansofthefirstfourmonthofevaluation(March-June2003,n=38).

WaterQuality Parameter	RawLiquid SwineManure (mg/L)	LiquidAfter SolidsSeparation Treatment (mg/L)	Efficiency (%)
TotalSuspendedSolids(TSS)	11,614	735	94
VolatileSuspende dSolids(VSS)	7,842	571	93
ChemicalOxygenDemand(COD)	21,283	6,598	69
ParticulateCOD	14,577	1,857	87
TotalKjeldahlNitrogen(TKN)	1,901	1,243	35
OrganicNitrogen	677	100	85
TotalPhosphorus	612	184	70
OrganicPhosphorus	445	46	90
Copper	25.5	1.0	96
Zinc	26.4	1.3	95
Iron	90.0	4.9	95

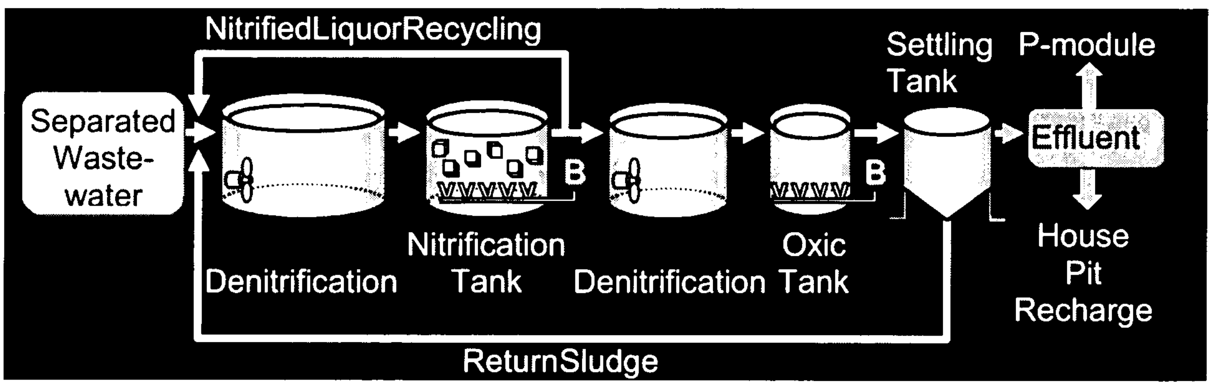
- Atotalof85trailerscontaining265m^{3}ofseparatedsolidswere producedandleftGoshen farmduringtheinitial4-monthevaluationpe riod(4/8-6/26).Thisamountofmanure weighedapproximately294,700kg(451,300lb) andcontained18.4%(±1.1%)ofsolids (81.6%moisture),1605kgofnitrogen,1051kgofphosphorus,87kgofcopperand83kgof zinc(Table2).

Table2:Amountandcompositionofsolidsproducedfromseparationtreatment(Ecopurinprocess). Concentrationvaluesareonadrymanurebasis.DataaremeansandtotalsobtainedMarch-June2003.

Element	Average Concentration(%)	Min-max Concentration(%)	Totalproduced (kg)
TotalNitrogen	4.26	3.49-4.94	1605
TotalPhosphorus	2.79	2.46-3.37	1051
Copper	[illegible]	[illegible]	

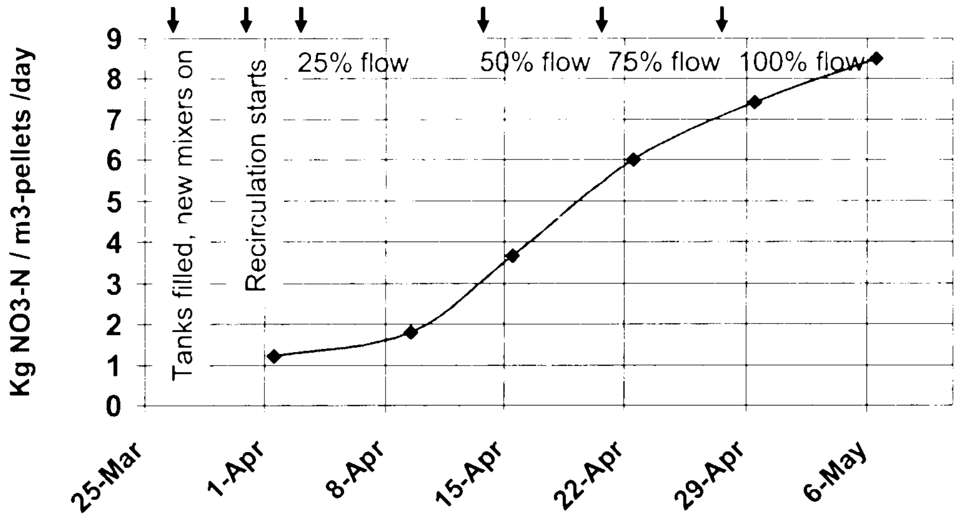
3.3 Biogreen N Removal Module

- Background: Once the solids are removed, a relatively smaller amount of suspended organic waste remains to be treated in the wastewater by the nitrification/denitrification. The liquid contains significant amounts of soluble ammonia and phosphorus. The demonstration project uses a Biogreen process (Hitachi Plant Engineering & Construction Co., Tokyo, Japan) that biologically removes the ammonia-N. The process has a pre-denitrification configuration where nitrified wastewater is sent through a denitrification cycle to remove most (>80%) of the nitrate using the soluble carbon (COD) contained in the manure after separation. A unique feature of the process is that the concentration of bacterial biomass in the nitrification tank is increased by using nitrifying bacteria encapsulated in polymer gel pellets. These pellets are permeable to ammonia and oxygen needed by the nitrifiers and are kept inside the tank by means of a screen structure. The reaction tank at Goshen contains 12 m^3 of the nitrifying pellets. There is a second denitrification tank built into the system where methanol can be injected for reducing the remain der nitrate in the effluent. This feature was not used during the first 3-months of operation summarized in this report in order to evaluate denitrification when effluent is recycled to recharge the pits under the houses. The following diagram illustrates the biological N removal module installed:



- Once the proper mixers and recirculation equipment were in place, it took about four weeks for the nitrifying bacteria to be fully acclimated to the high-strength swine wastewater (Figure 3). Acclimation process was carried out in a stepwise procedure where flow loads were increased from 25% of the flow being processed by the separation module to 100% (full-scale). Ammonia concentration in the effluent was monitored daily during this acclimation period using quick tests that were confirmed in the laboratory on a weekly basis. Pellets were sampled every week to conduct nitrification and respiration activity tests done in bench reactors also in the laboratory. For design purposes, pellets

Figure 3: Nitrification activity of pellets during acclimation to swine wastewater



- AmmoniaremovalefficienciesofBiogreen processwereconsistentlyhigh(>99%) duringboththefirstmonthacclimationperiodandthesubsequenttwomonthsevaluation includedinthisreport(April-June).Thesehighprocessefficiencieswereobtainedwith influentconcentrationsvaryingfromabout 500to1500ppmandeffluentconcentration< 10ppmthroughouttheevaluationperiod(Fig.4).AdecreaseinNconcentrationwas observedinJunecoincidingwithchangesinbatchesofpigsintheproductionhouses(50 lbpigsreplacingmarket250lbhogs).

- Aftersolidsseparation,mostoftheTKNwasmadeofsolubleammoniaandtherefore removalefficienciesforTKNwerealsohigh(98%).Thetreatmentalsosignificantly reducedalkalinity,volatilesolids,BODand CODconcentrationsintheliquideffluent (table3).Reducedmanurecarboncompounds wereconsumedmostlyinthefirst denitrificationtankandusedasanelectrondonorinthedenitrificationprocess.Inthe average,96%ofthesolubleCODand86%ofthesolubleBODthatwereremovedby treatmentwereconsumedinthistank(datanotshown).Methanolwasnotinjectedinto theseconddenitrificationta nkand asaresult [illegible]

[illegible]
removeasignificantmassofN(about32kg w eek)throughdenitrificationandthatthe liquidcontainedzeronitrateafterthisloop.StartingJuly15,2003,methanolwillbe

addedtothesecondenitrificationtanktotesttheBiogreenmoduleasoriginally designedandbeabletoproviderecommenda tionsonbestsystemoptionsforspecific situationsandenvironmentalgoals.

Figure 4: Treatment of nitrogen in biological N removal module

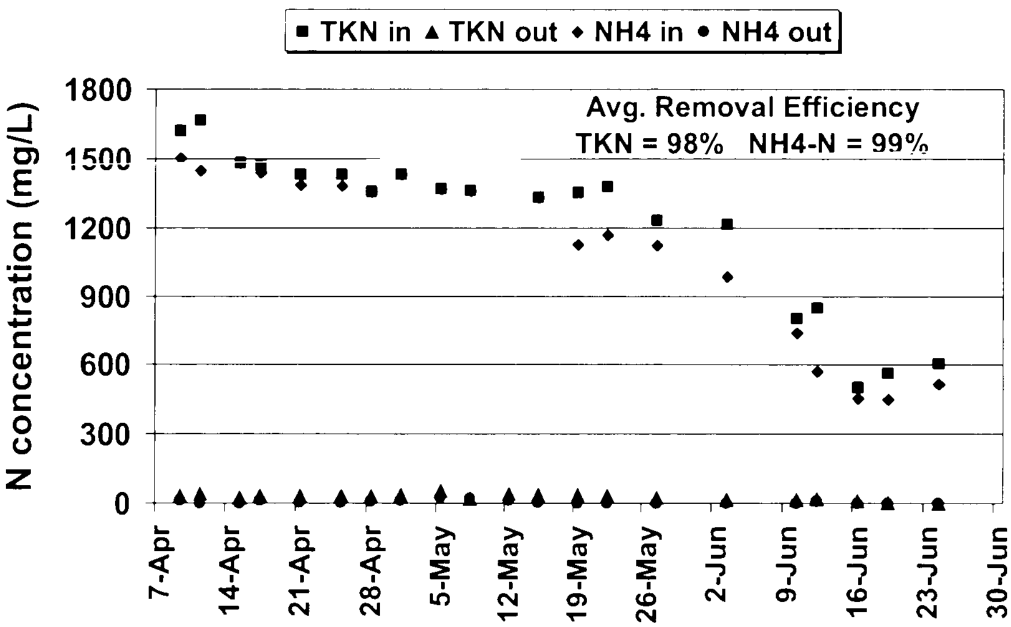


Table3:Removalofnitrogenandoxygendemandingcompoundsfromseparatedliquidswinemanureby biologicalNremovalmodule(Biogreenprocess).Data areaveragesofthefirstthreemonthsofevaluation (April-June2003,n=26).

WaterQuality Parameter	LiquidAfter SolidsSeparation Treatment (mg/L)	LiquidAfter BiologicalN Treatment (mg/L)	Efficiency (%)
Alkalinity	5,561	636	89
VolatileSuspended Solids(VSS)	530	72	86
ChemicalOxygenDemand(COD)	6,355	865	86
BiochemicalOxygenDemand(BOD [illegible])	[illegible]	[illegible]	
AmmoniaNitrogen(NH4 -N)	1,182	[illegible]	99

3.4 SolublePhosphorusRemovalModule

- Background:AfterbiologicalNtreatment,theliquidflowsbygravitytothephosphorus separationmoduledevelopedbyUSDA-ARSwherePisrecoveredascalciumphosphate andpathogensaredestroyedbyalkalinepH. Figure6showsaschematicdiagramofthe phosphorusseparationmoduleandfigure7showsadetailedpictureofthetechnology installedatGoshenRidgefarm.Liquid ismixedwithhydratedlimeinareaction chamber.ApHcontrollerislinkedtothe limeinjectorandkeepstheprocesspHat10.5-11.0.Theliquidandprecipitateareseparated inasettlingtank.Theprecipitatedcalcium phosphatesludgeisfurtherdewateredinfilterbagswithacapacityofabout50lbeach. PolymerisaddedtotheprecipitatetoenhancePseparation.Automationtothesystemis providedbysensorsintegratedtoaprogrammablelogiccontroller(PLC)24hr/day operation.ThePLCissharedwiththebiologicalNremovalmodule;treatment parameterssuchasprocesspHaresetbytheoperatorusinganothertactilescreeninthe plantcontrolpanel.

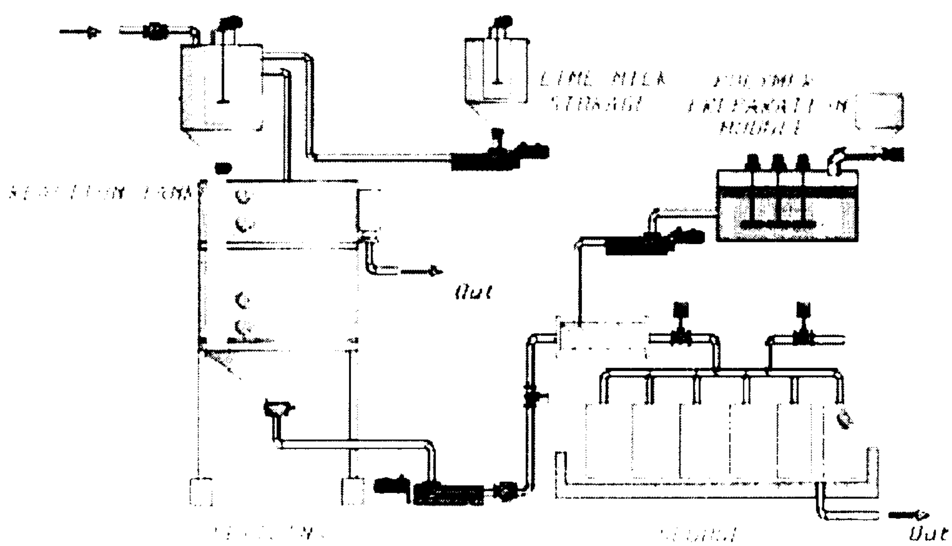


Figure6.Schematicdiagramofphosphorusseparationmoduleconstructedinthefull-scalemanure treatmentsystemdemonstrationprojectatGoshenRidgefarm,DuplinCounty,NC.

- EvaluationofthephosphorusmodulestartedApril15,2003,aftertheprecedingunitsin thetreatmenttrainwerebothinsteady-state.Resultsofthisevaluationforthe phosphorusmodulealonearesummarizedinFigure8andTable4. [illegible]

[illegible]agsandfertilizervaluedeterminationswerestarted[illegible]measurementsarestillin progress.

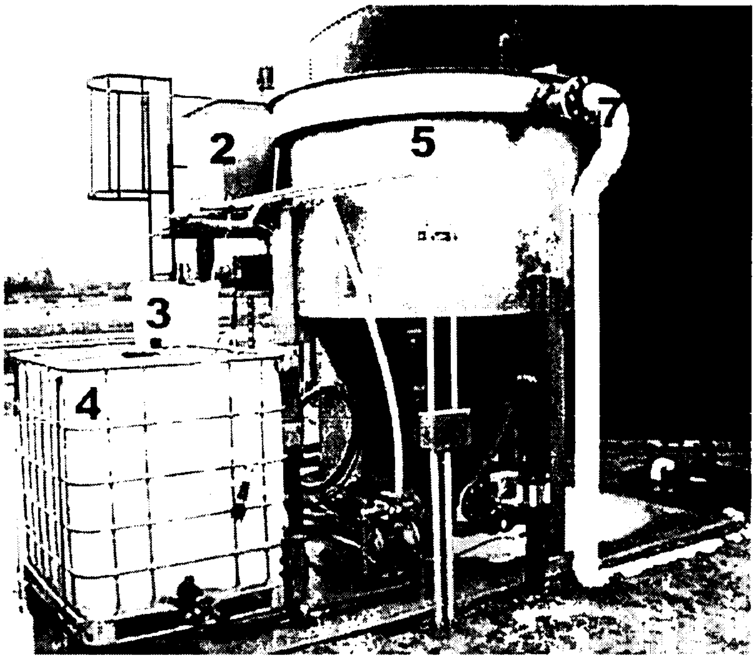
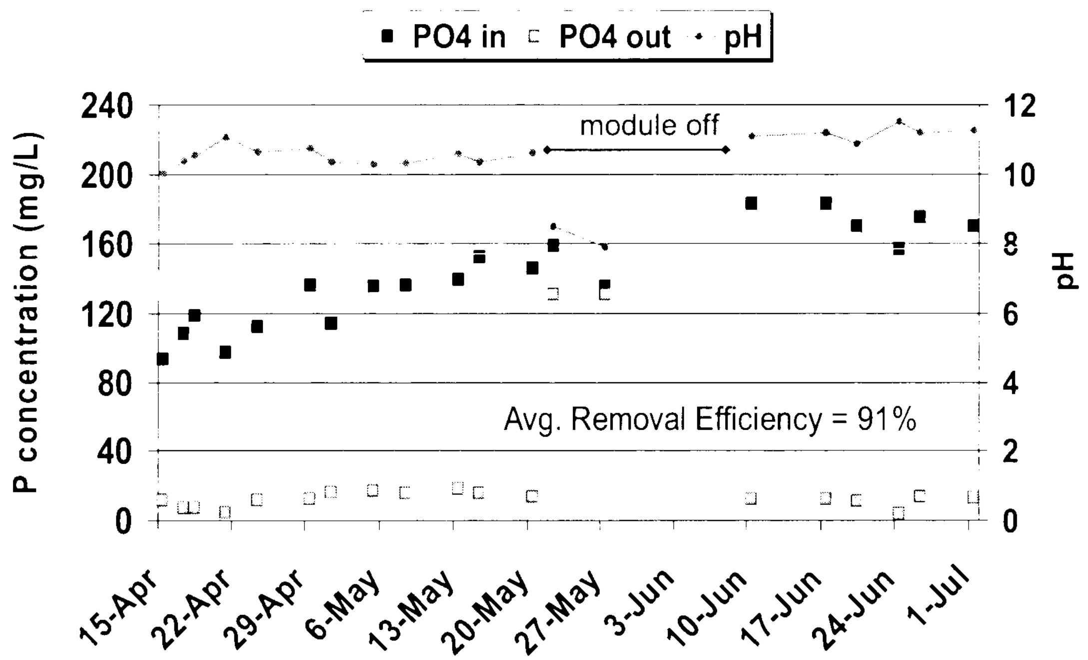


Figure 7. Phosphorus separation reactor installed on a hog farm in Duplin County, NC. Storage tank (1) in background holds wastewater from which ammonia nitrogen and carbonate buffers have already been removed. This wastewater gravity flows to reaction chamber (2) along with a slurry of water and hydrated lime suspended in mixing chamber (3). More lime slurry is stored in a container (4) until needed. Liquid flows from the reaction chamber (2) into cone-shaped settling tank (5). There, phosphorus sludge settles to the bottom (6) and is later removed, filtered, and dried in filter bags. Cleaned wastewater flows from top of settling tank via the white pipe (7) and is delivered to sump (8). An underground pipe carries cleaned wastewater to nearby subsurface irrigation system for crops.

Table 4: Removal of phosphorus from liquid swine manure after biological N treatment (ARS process). Data are averages of the first 2.5 months of evaluation (April 15 - July 1, 2003, n=21).

Water Quality Parameter	Liquid After Biological N Treatment	Liquid After Phosphorus Treatment	Efficiency (%)
pH	7.59	10.72	--
Alkalinity, mg/L	615	879	--
BOD_5, mg/L	16	7	56
[illegible]	[illegible]		

Figure 8: Removal of soluble phosphorus in P-module. PO_4-P concentration values shown in left axis and process pH indicated in right axis.



3.5 SystemPerformance

- Systemperformancedatawa sobtainedduringarelativelyshortperiod(April15-July1, 2003)whenallthreemoduleswerein-line(Table5).Thedatashowtheunique contributionsofeachcomponent totheefficiencyofthetotalsystem.Overall,the demonstrationsystematfull-scaleperformed todesignexpectationsorbetterwith respecttonutrientandheavymetalelimination.

- Thesystemhasbeensuccessfullystabilizedandbroughttosteadystateduringthis reportingperiod.Itwasobservedalsoth at,asoperatorsbecomefamiliarwiththe

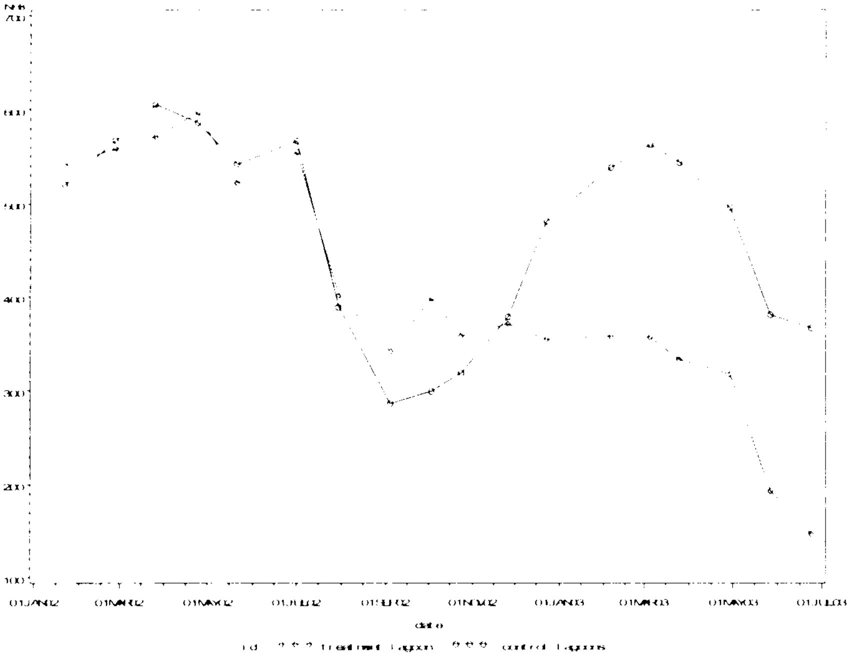
Table5:RemovalofsuspendedsolidsCOD,BOD,andnutrientsbytotaltreatmentsystematGoshenfarm. DataaremeansfortheperiodofApril15-July1,2003whenall threemoduleswerein-line(n=21).

WaterQuality Parameter	Raw Flushed Manure	AfterSolids Separation Treatment (mg/L)	After BiologicalN Treatment (mg/L)	After Phosphorus Treatment (mg/L)	System Efficiency (%)
TSS	10,441	679	129	268	97.4
VSS	7,420	516	67	88	98.8
COD	19,554	6,411	867	694	96.5
BOD_5	6,425	3,305	16	7	99.9
TKN	1,975	1,241	32	24	98.8
NH_4-N	1,242	1,166	9	1	99.9
TP	596	192	149	31	94.8
PO_4-P	172	142	138	12	93.0

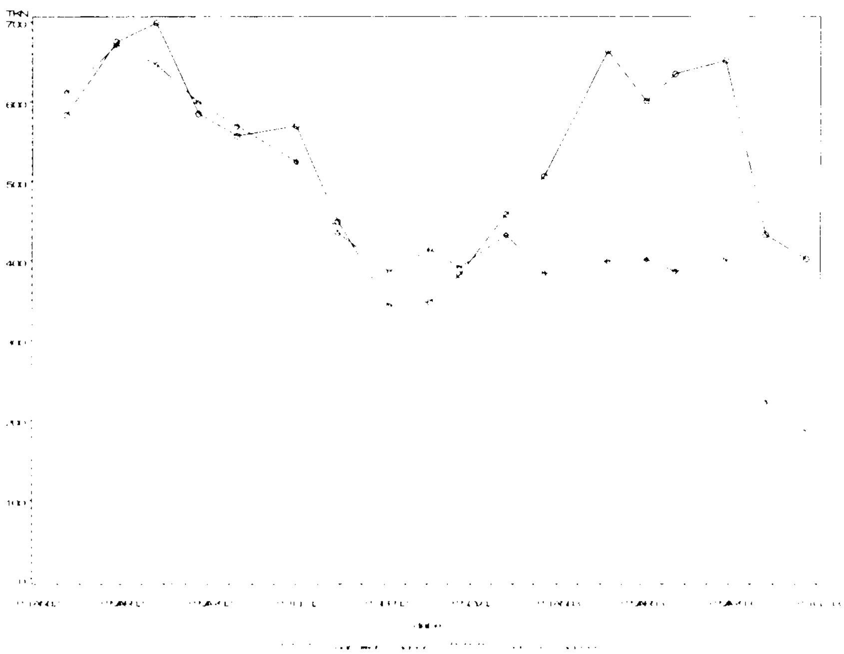
3.5Lagoons

- Compositesamplesfromthethreelagoonsinthesamefarmwerecollectedmonthlysince January2002andanalyzedforwaterqualitycharacteristics.Duringyear2002,thethree lagoonsstoredandtreatedthewastefromsixhouseseachwithsimilarnumberofpigs andproductionmanagement.Totalnitrogenconcentration variedfromahighatendof winterofabout700ppmtoalowattheendofsummerofa bout350ppm;ammonia-N followedsamepatternandvariedfroma bout600to300ppm,respectively.Inthe average(seetable),theconcentrationsofnitrogen,COD,volatilesolids,electrical conductivityandphosphorusduring2002were similaramonglagoons.Sludgedepths weremeasuredbyPremiu mStandardFarmsintheFallof2001and2002averaging 23.6",19.3"and18.8"forlagoons#1,2,and3,respectively.

Year	Lagoon	TKN (mg/L)	NH_4-N (g/L)	COD (g/L)	VSS (g/L)	EC (mS/cm)	TP (g/L)
2002(Jan.-Dec)	#1Traditional	0.51	0.46	.7 0.	19 7	.7 0.	3
	#2Traditional	0.52	0.47	.7 0.	22 7	.2 0.	3
	#3Traditional	0.52	0.47	.7 0.	22 7	.3 0.	2
	#3Traditional	0.51	0.43	.7 0.	26 6	.5 0.	11



NH3
700
600
500
400
300
200
100
01JAN02
01MAR02
01MAY02
01JUL02
01SEP02
01NOV02
01JAN03
01MAR03
01MAY03
01JUL03
date
treatment lagoon
control lagoons



TKN
700
600
500
400

- Significant differences in water quality characteristics among lagoons were observed starting in 2003 after manure flush to lagoon #1 was halted and 100% of the manure generated was processed through the treatment plant. Treated liquid during this period was discharged into the lagoon. These differences include lower concentration of ammonia, TKN, COD, VSS and conductivity in the lagoon that was replaced by the treatment plant compared with values observed in the control lagoons. Ammonia concentration at the end of this reporting was the lowest (146 ppm). Evolution during the second half of year 2003 will provide a better understanding on lagoon cleanup when systems without lagoon are retrofit to existing operations that use anaerobic lagoon technology.

4. Other Activities During Reporting Period

4.1 Testing and Research

- Oct. 2002-Feb. 2003. Tests and analytical work done at ARS Florence laboratory to support polymer optimization and calibration of the separation module equipment.
- Jan-June, 2003. Nitrification activity and respiration activity of pellets were tested weekly in reactors at ARS Florence laboratory to support acclimation and stabilization of Biogreen module. A cold winter simulation experiment using a chilled continuous flow bench reactor was initiated May 2003.
- Feb.-June, 2003. Dr. Vanotti, Mrs. Aprel Ellison and supporting staff visited Goshen treatment system every week to conduct system evaluations.
- April-May, 2003. Denitrification and respiration activity of denitrifying biomass were tested in reactors at ARS Florence laboratory to support technology provider with acclimation and stabilization of Biogreen module.
- April 9, 2003. A SCADA (supervisory control and data acquisition) network developed by Selco MC was successfully installed at Goshen plant to assist in technology evaluation and process monitoring from remote location.
- April-June 2003. The original Biogreen pilot unit (1 m^3/day) used to develop the full-scale system was installed at Goshen facility. Experiments conducted by Drs. Sumino and Vanotti were started to evaluate feasibility of increasing ammonia treatment capacity of demonstration unit and second generation modifications needed to process waste from 8800 pigs (two farms).
- April 21-May 2, 2003. OPEN team conducted warm weather evaluation of emissions (odor, pathogens and nitrogen) in Goshen treatment system.
- June 10-24, 2003. Set-up and planting of irrigation plots in former sprayfield adjacent to treatment plant modified into a subsurface drip irrigation (SDI) system to use the treated

Maintenance for the complete Goshen treatment system

4.2Visits/tours/presentations/press

- Sept.24,2002.Agroupofabout30scientistandrepresentativesofARS,NRCS,and EPAtouredtheGoshensystemandSolidsProcessingfacilityaspartoftheAnimal WasteTreatmentTechnologiesWorks hop,ARSNationalProgram#206'Manureand By-productUtilization'.
- Nov.24,2002.Projectfeaturedincoverpage article"ModernAgriculture:Technology helpsfarmers"inTheFayettevilleObserver.
- Jan.16,2003.TourofGoshentreatmentsystembyNationalPorkBoard'sEnvironmental Committee.
- Jan23,2003. IMCrepresentativesvisitedGoshenprojecttoinspectcalciumphosphate productionmodule.
- Jan.24,2003.PhosphorusremovalmoduletechnologyannouncedinNewsRelease 0025.03byAgricultureSecretaryAnnVeneman. www.ars.usda.gov/is/pr/2003/030124.htm
- April1,2003.EnvironmentalManagementSolu tions(EMS)directorsvisitedtreatment systematGoshenandSolidsProcessingfacility.
- EngineersMiriamLorenzoandJorgeBarrera,andDeputyGeneralManagerMr.Jesus MartinezAlmelaof SelcoMC,SpainworkedatGoshensiteduringNovember2002,and FebruaryandApril2003tooptimizese parationmoduleandoverviewproject engineering.
- April-June,2003.Drs.Osman,SuminoandEmor yofHitachiPlant,Japanwereat Goshensiteduringthreemonthstooverviewstart-upandstabilizationofBiogreen module.
- June16,2003.JohnDeererepresentativestouredGoshentreatmentplant.
- June24,2003.Dr.VanottiassistedMr.Ken EllzeyofDep.CommunicationsServices, NCSU,videotapingthetreatmentplantforprodu ctionofaVirtualTourtobeshownat theNCSUWasteManagementWorkshopOct.16-17,2003.
- June24,2003.Dr.Vanottipresentedaprojectupdateat4 thNationalWorkshopon ConstructedWetlands/BMPsforNutrientReductionandCoastalWaterProtection, Wilmington,NC,sponsoredbyEPAand NCSU.Apaperwasdistributed.
- June25,2003.Drs.Vanotti,SzogiandHunt(ARS)metatNCSUwithDr.Williams, HitachiPlantengineers(Drs.EmoryandOsman),andSuperSoilSystemsUSA representatives(Mr.Fetterman,Dr.Campbell,andMrs.KimMcLawhorn)todiscuss BiogreenNremovalmoduleprogress andsecondgenerationsystems.

<u>ProjectDelaysorDifficultiesExperiencedforCurrentReportingPeriod</u>:

processeswererapidlystabilizedthereafter.Th scontributedtoaprojectdelayofabout 90days.

- Operation of phosphorus module was halted in late May-early June after the cpu circuit controlling the nitrogen and phosphorus modules was damaged. The circuit was replaced and reprogrammed quickly (<48 hrs) but a change in calibration in pH sensor resulted in about two week down-time. A routine was established afterwards for weekly probe maintenance and calibration.

Objectives and Concise Work-plan/Timeline for Subsequent Project Duration:

1. **Objectives:**

- To demonstrate and provide critical performance evaluation of the Swine Manure Treatment System and Solids Processing Technologies in Proposal #001 Project Award, NC Attorney General/Smithfield Foods & Premium Standard Farm Agreements, to determine if the technology meets the criteria of Environmental Superior Technology defined in section II.C.1.5 of the Agreement. Specifically, performance standards related to the elimination of discharge into waters and elimination of nutrient and heavy metal contamination of soil and groundwater.

- To use process information to support demonstration project and improve operation of the full-scale system.

2. **Work-plan/Timeline:**

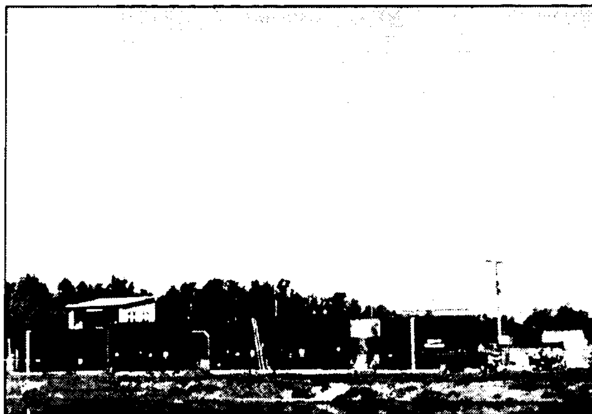
- Quality of compost products will be evaluated Sept.-Oct. when the first composting and solids product batches are available.

- Sampling evaluation and monitoring of the wastewater treatment system will be extended to October 31, 2003 to include the second OPEN team evaluation (Cool weather) scheduled for the weeks of October 20 and October 27, 2003.

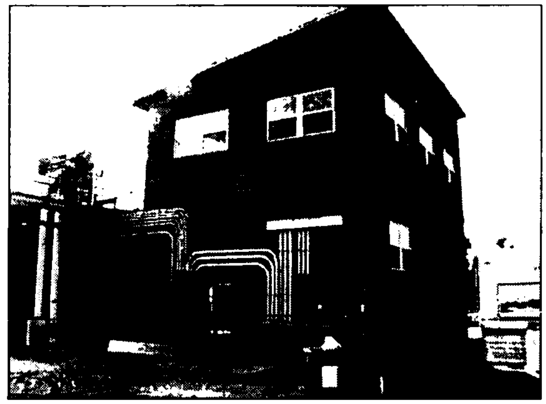
- Mass balances of nutrient will be completed November 2003. Information will be provided to Economic team for their modeling analysis.

- Verification reporting to Designee is expected Dec., 2003.

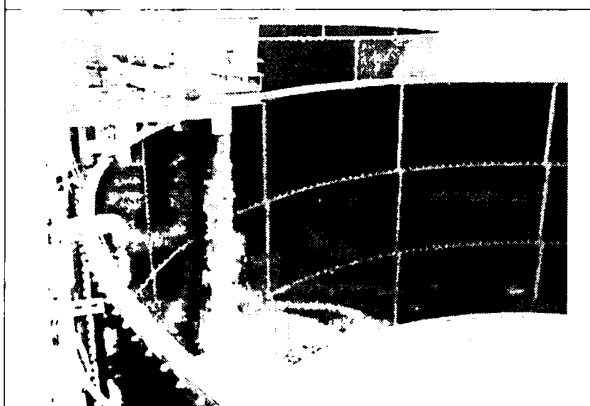
Appendix:ProjectPictures



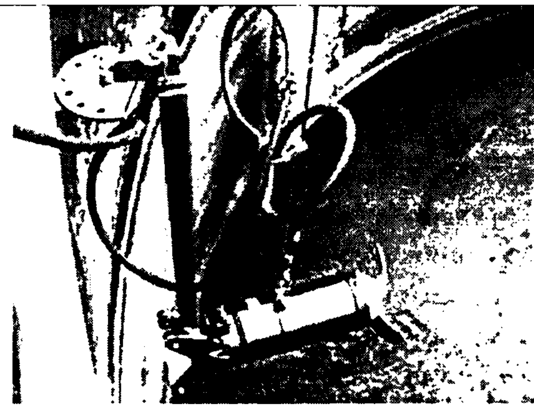
TreatmentsystematGoshenRidgefarm.



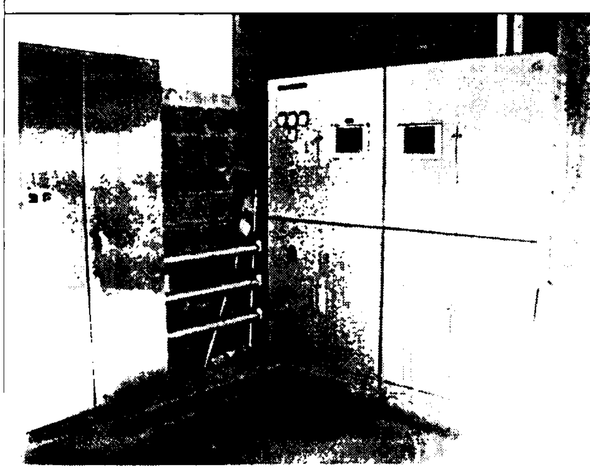
Solid-liquidseparationbuilding.

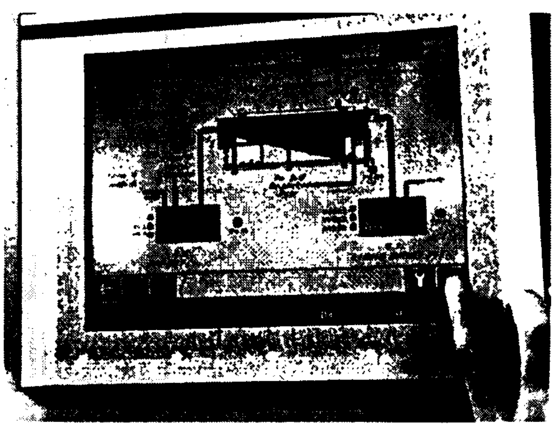


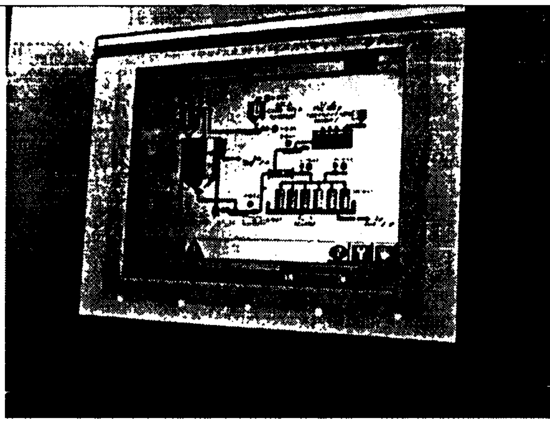
Homogenizationtank



Mixerwithrailusedinhomogenizationtank



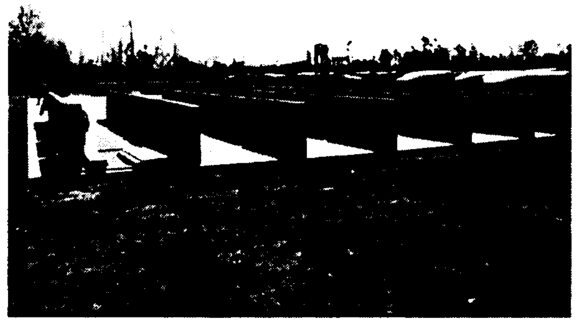




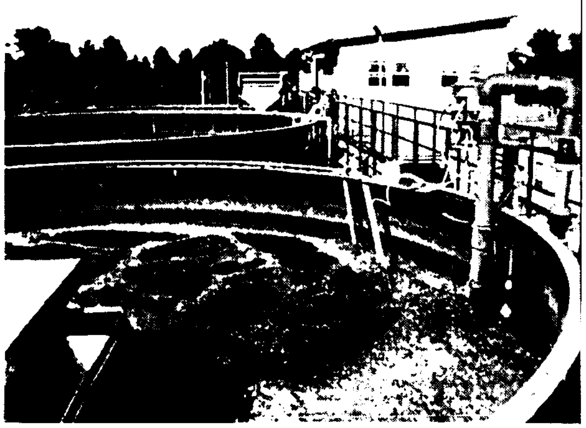
Phosphorus module control screen

Automated refrigerated sampler used for evaluation

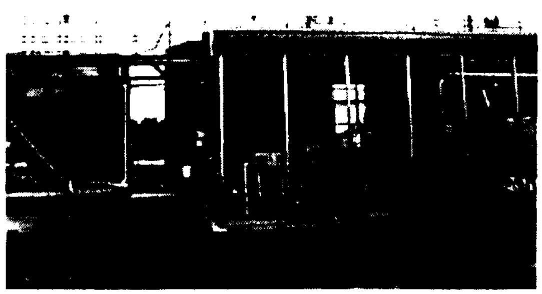
Solids processing building built in Sampson County



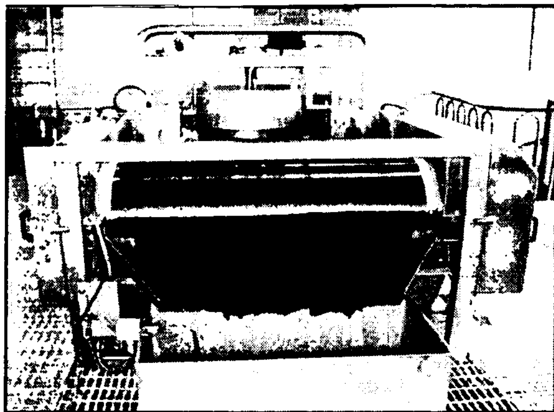
Composting bins at solids processing facility.



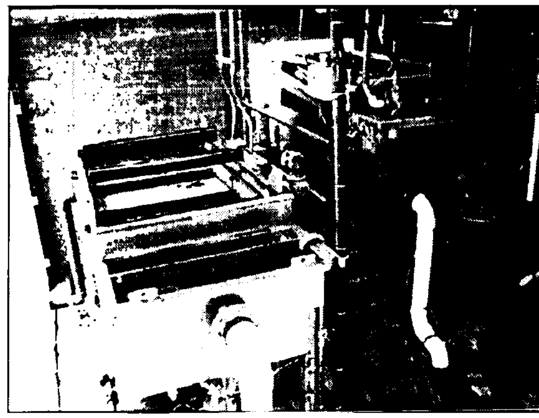
Nitrification treatment tank at Goshen Ridge facility



[illegible] pilot and full scale plants at Goshen Ridge



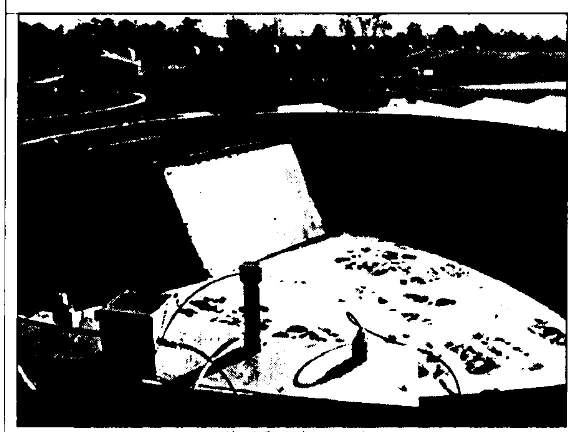
Solid-liquidseparationreactor.



DAFanddewateringfilterpressinseparationmodule.

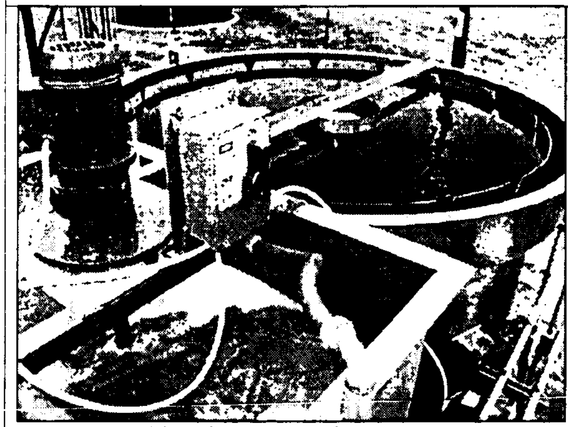
Separatedliquid,liquidbeforeDAF,andrawmanure.

Separatedsolidsafterfilterpress

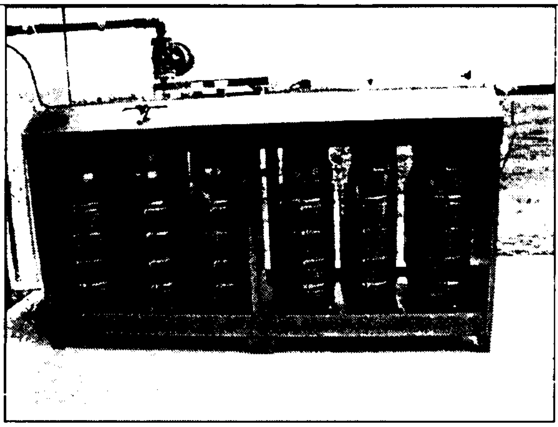


Nitrificationtank.

Nitrifyingpellets.



Phosphorusseparationreactor.



Dewateringandbaggingofcalciumphosphateproduct.

Phosphorusprecipitateandtreatedeffluent.

Dewateringofphosphoruswithfilterbag.